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PRELIMINARY REPORT ON THE ADEQUACY OF WATER IN THE YAKIMA RIVER BASIN, WASHINGTON

Donald P. Dubois

Public Health Service
Portland, Oregon

August 1963

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Working Paper No. 44

COLUMBIA RIVER BASIN PROJECT
For Water Supply and Water Quality Management

PRELIMINARY REPORT ON THE ADEQUACY OF WATER IN THE YAKIMA RIVER BASIN, WASHINGTON

DATE: August 1963

Prepared by DPD

Reviewed by JLA

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Water Supply and Pollution Control Program, Pacific Northwest
Portland, Oregon

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This working paper contains preliminary data and information primarily intended for internal use by the Columbia River Basin staff and cooperating agencies. The material presented in this paper has not been fully evaluated and should not be considered as final.

Preliminary Report on the Adequacy of Water in the Yakima River Basin, Washington

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Water Supply and Pollution Control Program, Pacific Northwest

Portland, Oregon
August 1963

PREFACE

This report was originally intended to be a finished document describing the adequacy of water in the Yakima Basin, Washington. When a draft was finished, however, it appeared that no important knowledge would be added to the water resources field by the report and, secondly, the report was somewhat out of sequence with the development and presentation of comprehensive studies in the Basin. For these reasons, the report was never completed in finished form but is compiled as a working paper for general use by the Columbia River Basin Project personnel working in the Basin.

Donald P. Dubois
Sanitary Engineer
August, 1963

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
	A. Purpose of the Report	1
	B. Description of the Basin	1
	C. Economy of the Basin	2
II.	SURFACE WATER SUPPLY	3
	A. Regulation	3
	B. Floods	5
	C. Water Use	5
	D. Summary	7
III.	GROUND WATER	9
	A. Ground Water Supply	9
	B. Ground Water Quality	12
IV.	SURFACE WATER QUALITY	16
	A. Water Quality Data Collection Programs	16
	B. Factors Affecting Water Quality	18
	C. Water Quality Parameters	20
	1. Common Mineral Ions	20
	a. Chloride	21
	b. Hardness, Calcium, and Magnesium	22
	c. Sulfates	24
	d. Sodium and Potassium	25
	2. Other Chemical Parameters	26
	a. Alkalinity	27
	b. Fluoride	29
	c. Hydrogen Ion Concentration	29
	d. Iron and Manganese	31
	e. Nitrate	32
	f. Oxygen	34
	g. Phosphates	36
	h. Silica	38

Page

3. Physical Parameters 39

a. Color 39
b. Solids 40
c. Temperature 44
d. Turbidity 47

4. Biological Parameters 48

a. Bacteria 48
b. Plankton 51

V. INTERPRETATION OF WATER QUALITY DATA 52

A. Physical and Chemical Constituents 52

1. Irrigation and Industrial Use 52
2. Public Water Supply Use 52
3. Fish Habitat 53
4. Recreational and Aesthetic Value 54

B. Biological Constituents 54

1. Industrial Use 54
2. Public Water Supply Use 55
3. Recreation and Aesthetic Use 56

C. Adequacy of Water Data 56

VI. APPENDIX 58-

I. INTRODUCTION

A. Purpose of the Report

A number of individuals and organizations have gathered water quality and quantity data in the Yakima Basin. A portion of these data have been collected for the purpose of answering specific questions; other data have been collected on a routine basis and published without analysis or comment. The purpose of this report is to bring these data together and interpret them so that they will have greater meaning and be of greater usefulness. It is the opinion of the Public Health Service that a periodic review should be made of data collecting programs to see that the proper data are being collected at proper time and distance intervals to provide adequate information without needless duplication of effort.

B. Description of the Basin

The Yakima River system drains an area of some 6,000 square miles of central Washington. The Yakima River and its main tributaries originate on the eastern slope of the Cascade mountain range where the average annual precipitation exceeds 100 inches at several points. From its source in the Cascade Range, the River flows in a southeasterly direction for approximately 205 miles to its confluence with the Columbia River near Richland. Precipitation in the lower portion of the Basin is less than ten inches per year in most places.

The slope of the river is fairly steep over most of its length; ranging from over twenty feet per mile in the upper reaches to less than two feet per mile for short stretches in the lower reaches. The portion of the Basin above Cle Elum is forested with evergreen trees as are the Naches and Tieton drainage areas above the confluence of the two rivers. The remaining portion of the Basin is largely treeless with vegetation consisting of sagebrush and various grasses.

The Yakima Valley is generally separated into three distinct areas; that portion above Wilson Creek, the portion between Selah Gap and Union Gap, and the portion below Union Gap. The area between Selah Gap and Wilson Creek, a distance of twenty-five to thirty river miles, is a steep-walled canyon.

C. Economy of the Basin

The 1960 population of the Yakima Basin totaled approximately 203,000. Table 1 shows the change in population between 1950 and 1960 for the three counties in the Yakima Basin as compared with the total Oregon-Washington trend for the same period.

Table 2 of the Appendix shows the distribution of the employed civilian labor force by industry in the Yakima Basin for 1950 and 1960. It can be seen that the economy of the Basin is based largely on agriculture and the Hanford Atomic Works. The latter industry is located only partially in the Basin and its economic effect is felt largely in communities located outside the Basin. It is evident, also, that the number of persons employed in agriculture and construction is decreasing while employment in manufacturing and service industries is increasing.

Table 1

Change in Population 1950-1960
Benton, Kittitas and Yakima Counties
Compared with Oregon-Washington a/

	1950	1960	Rate of Increase, Compounded Annually, Percent
Benton	51,370	62,070	1.9
Kittitas	22,235	20,467	Decrease
Yakima	135,723	145,112	0.7
3-County Area	209,328	227,649	0.8
Oregon-Washington	3,900,304	4,621,901	1.7

a/ U. S. Census, as of April 1.

II. SURFACE WATER SUPPLY

A. Regulation

Stream flow in the Yakima River Basin is sharply influenced by man-made facilities. Six regulating reservoirs, with a total capacity of slightly more than one million acre-feet are located in the Basin. Numerous diversions for irrigation and power generation also markedly influence flows in the river. Three of the reservoirs, Keechelus, Kachess and Cle Elum, are enlargements of natural lakes, and are located on the Yakima and tributaries to the Yakima River above the town of Cle Elum. Bumping Reservoir is located on the Bumping River, a tributary to the Naches, and is also an enlargement of a natural lake. Tieton (now called Rimrock) Reservoir impounds Tieton River water. Clear Creek Reservoir, with a capacity of only 5,300 acre-feet is located on the Tieton River one mile above Tieton (Rimrock) Reservoir and is not normally operated. Wenas Reservoir, located on Wenas Creek, has a capacity of some 1,500 acre-feet and is used to provide irrigation water in the Wenas Creek Valley.

Regulation in the Basin is for the purpose of providing irrigation waters in the quantity and at the time they are needed. Flood control benefits are provided only as they do not interfere with irrigation. The operating schedule consists of stopping releases from four of the reservoirs at the end of the irrigation season so that they may fill as rapidly as possible. A flow of twenty-five to thirty cubic feet per second is maintained in the Cle Elum River

below the dam to meet water supply needs of the City of Cle Elum. Releases from storage may begin as early as April or as late as July, depending on runoff conditions.

Major diversion from the Yakima include the Kittitas High Line Canal at Easton, the Roza Canal some fifteen miles above Yakima, the Wapato Canal five miles below Yakima, the Sunnyside Canal eight miles below Yakima, and the diversion for power and irrigation of land in the Kennewick area at Prosser. The major diversion in the Naches River sub-basin is from the Tieton River eight miles below Tieton Dam.

Figure 1 indicates the average annual flow of the Yakima River at Cle Elum, Umtanum (just above the Roza diversion), Parker (just below the Wapato and Sunnyside diversions) and at Kiona. Except in the case of the Kiona station, the period of record shown reflects the flow as it applies today; that is, after major diversions have been placed in operation to alter long term records. The Kennewick Canal which by-passes the Kiona station was not placed in operation until August, 1956. The Kennewick Canal has an average flow of approximately 100 cfs.

As was mentioned earlier, there is a great deal of regulation of the river and, hence, the relative proportion of stream flow for various reaches of the river changes markedly with the season. Figure 2 shown graphically the stream flow in the basin for the July through September period.

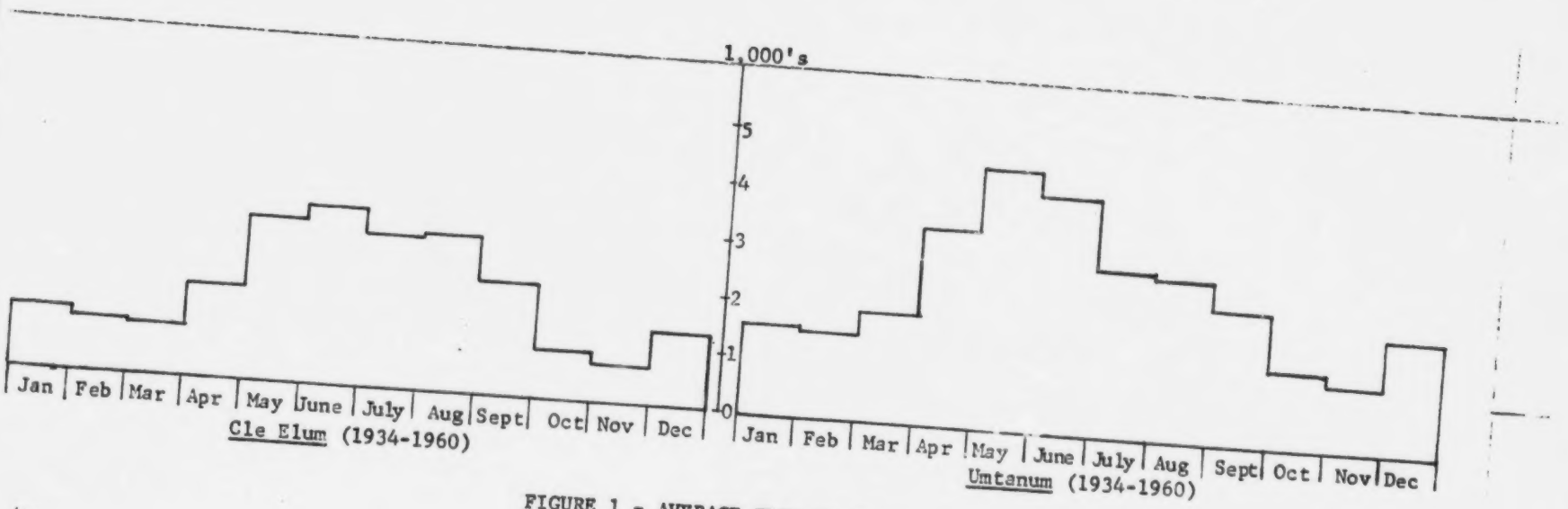
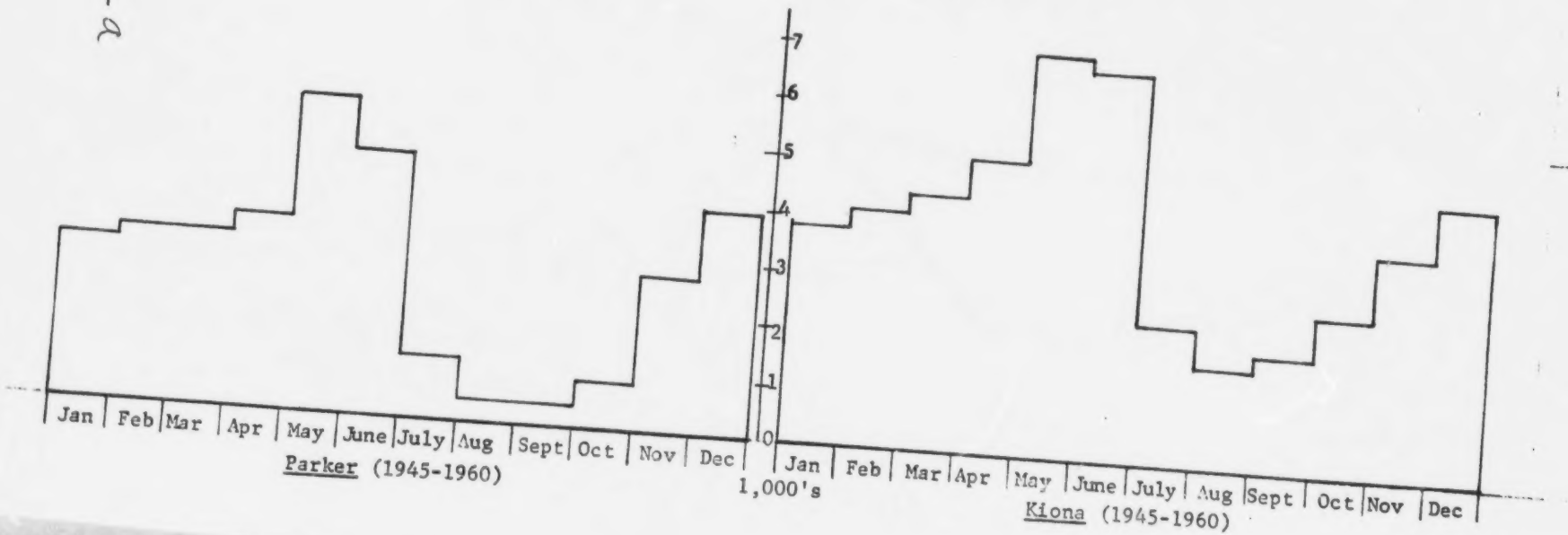


FIGURE 1 - AVERAGE FLOW BY MONTH

5-a



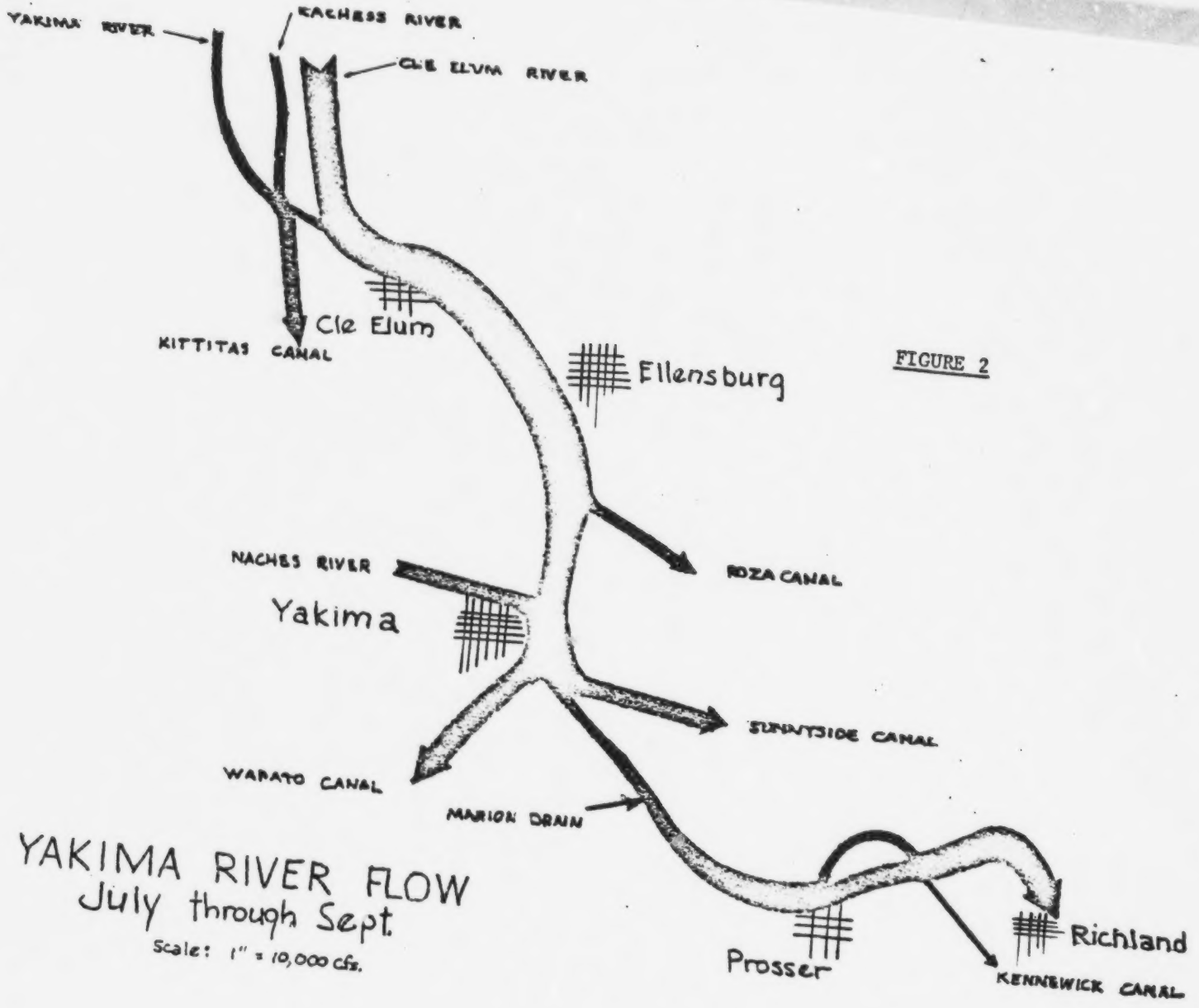


FIGURE 2

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B. Floods

Floods of various magnitude have plagued the Yakima Valley from time to time. Major floods of unknown magnitude occurred seven times in the Valley between 1862 and 1896. Stream gaging was initiated in 1896 and since that time eight major floods have occurred. The December 1933 flood was the last flood of record in the lower Yakima Valley. The Corps of Engineers estimated that, under conditions of 1949 land use and at 1950 prices, damages of approximately $3.25 million would occur in a flood equal to the 1933 flood. The largest spring flood occurred in May of 1948 and under the circumstances mentioned above damages of $2.44 million would result.

C. Water Use

Irrigation is the dominant water use in the Yakima River Basin. Some 2,340,000 acre-feet per year of surface water is used for this purpose. This over-shadows the municipal use of approximately 1,100 acre-feet and the industrial use of some 10,000 acre-feet of surface water.

Water in the Yakima Basin as in most western river basins is subject to the "doctrine of prior appropriation." The essence of this doctrine is that an individual or group of individuals may obtain a right for the use of water irrespective of their location in the Basin and their right must be honored before subsequent rights when adequate flow is not available to satisfy all rights.

The total rights of storage and power users diverting water above Sunnyside Dam are 2,680,400 acre-feet annually.[1/] Of this total, 2,232,200 acre-feet are for irrigation purposes alone and will be used during the months of April through October. The average annual discharge for the 58 years between 1897 and 1954 and 3,098,000 acre-feet at the Parker gaging station.

The Bureau of Reclamation [1/] estimates that, with ultimate development of irrigable land and existing storage facilities, shortages of irrigation water would have occurred five times in the past year.

Rights to divert waters of the Yakima River were adjudicated by the Court in 1945. The Court decision, known as the Consent Decree, set forth the amount of water each user or district is entitled to receive and classified the rights into proratable and non-proratable rights. Non-proratable rights are those which were established first and in the case of a water shortage would be supplied first. Proratable rights, as the name implies, would receive an amount less than their normal total in case of a water shortage. Fifty-seven percent of the water rights for irrigation in the Yakima River above Sunnyside Dam are proratable.

1/ U. S. Bureau of Reclamation 1956 Report.

D. Summary

In the above discussion, it is apparent that summer flows including releases from storage are essentially completely appropriated and that shortages can be expected to occur periodically with utlimate development of present irrigation projects and no increase in storage.

As was pointed out in the opening section of the report, very low flows exist in certain reaches of the river during certain seasons. Low flows in the river reach below the storage dams occur during the reservoir filling period in the fall. These low flows create a hazard to the spawning of salmon by preventing fish passage and preventing the development of eggs laid in the stream bed before subsistence of the water level. Low summer flows in the lower reaches are also detrimental to fish passage, both from a quantity standpoint and from a temperature and quality standpoint. The low flows in this reach affect water quality and temperature by insufficient dilution of warm and highly mineralized irrigation return flows and to a lesser extent municipal and industrial wastes.

The adequacy of the water supply would be increased by a Bureau of Reclamation proposal to increase the capacity of Bumping Reservoir from its present 32,600 acre-foot capacity to 420,000 acre-feet. Under the proposed plan, some 100,000 acre-feet of the storage would be provided for irrigation and flood control and approximately 320,000 acre-feet would be provided for quality control and to maintain minimum

flows for fish passage. With the increased storage capacity, a minimum of 50 cfs could be provided all of the streams below reservoir and diversions except at the Wapatox power diversion on the Naches River where a 43 cfs minimum would be provided during the winter months. A minimum average monthly flow of 230 cfs would be allowed to pass Sunnyside diversion dam during the summer months. It is also estimated that water shortages for irrigation would be less severe during dry years and that a 8,000 to 10,000 cfs reduction in flood flows at Parker could be effected.

III. GROUND WATER

A. Ground water supply

The ground water resources of the Yakima Basin are an important complement to the surface water resources of the area. All of the municipalities in the Basin except Roslyn and Easton utilize ground water for municipal water supply purposes. Cle Elum, Ellensburg, Richland and Yakima obtain a portion of their supply from surface water. In addition, ground water is used extensively for individual industrial and domestic purposes and for irrigation. Well logs for over four hundred wells in the Yakima are on file with the Washington State Department of Natural Resources. The U. S. Geological Survey lists the 1951 ground water withdrawals in the Basin as: 1/

Irrigation	23,900 acre-feet per year
Industrial	14,600 acre-feet per year
Municipal	7,800 acre-feet per year
Domestic	5,365 acre-feet per year
Total	51,665 acre-feet per year

Surface water rights for irrigation projects approximated one hundred times the amount of ground water used for irrigation in 1951. In certain areas of the Basin, however, irrigation with ground water plays a more important role.

1/ "Geyhydraulic Evaluation of Streamflow Records in the Yakima River Basin, Washington", Jack E. Sceva, U. S. Geological Survey, Water Resources Division.

The area of most intense ground water use is in the Ahtanum Valley. Some twenty-five percent of the total number of wells in the Basin (as indicated by the recorded well logs) are located in this area and the area leads all others in ground water use, according to the U. S. Geological Survey figures. 1/ Approximately 6,300 acre-feet per year of ground water is used in this area, mainly for irrigation. The area of the Ahtanum Valley where ground water development has taken place is approximately one hundred square miles.

It is estimated that withdrawals from the basalt (deep) formation could be increased somewhat without exceeding the long term yield. It is recommended 1/ that any additional wells be spaced as far as possible from other wells to prevent interference. Any future major increase in withdrawals from the unconsolidated alluvium (near surface) should be given careful consideration before being attempted. Increased withdrawals from this formation would tend to lower the water table which would be desirable from the standpoint of drawing water logged areas and would reduce the water loss from non-beneficial evaporation and plant transpiration. However, in areas near surface waters, additional water would tend to leave the stream and enter the ground, then reducing stream flows. This lessening of stream flow may not occur, however, until after the irrigation

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1/ This material abstracted from "Geology and Ground Water Resources of the Ahtanum Valley, Yakima County, Washington", by Bruce L. Foxworthy, U. S. Department of the Interior, Geological Survey, Open-file Department, August 1959.

season. Secondly, evaporation and transpiration from new irrigated areas would increase. The net result of these factors seems to be that an increase in irrigated land, using ground water, could be accomplished if properly planned without seriously depleting the ground or surface supply.

The main area of ground water use in the Wenas Creek Valley is in the lower portion of the Valley. Some 2,200 acres were irrigated with an estimated total of 4,000 acre-feet in 1948. Only about fifty acre-feet was used in the upper portion of the Valley. It is further estimated that not over one hundred acre-feet of ground water is used for stock watering and domestic use. Thus, the total ground water use in the Valley was approximately 4,150 acre-feet in 1948. It was reported 1/ that there was (in 1949) "no indication that the safe yield of the water-bearing formations had been reached." It was also indicated that no decline in water levels had been recorded in the upper Ellensburg formation of the lower valley which is the main water producer. It was estimated that some 10,000 acre-feet per year of water could be pumped from this formation without appreciable perennial lowering of the water table. It was cautioned, however, that adequate data on part water levels had not been available and stated that an accurate record of pumpage and water levels should be maintained to establish a better estimate of the safe yield of the Basin.

1/ Unpublished report entitled "Geology and Ground Water Resources of the Wenas Creek Valley, Yakima County, Washington," by J. E. Sceva, F. A. Watkins, Jr., and W. N. Schlax, Jr., 1949 (USGS), in cooperation with the Division of Hydraulics, Washington State Department of Conservation.

The U. S. Geological Survey has not made detailed surveys of other areas in the Yakima Basin. Information available in the files of the Division of Water Resources of the State of Washington indicates that in general the more productive wells needed to supply irrigation and municipal water are in either the relatively deep basalt formations or in shallow alluvial formations, generally near surface waters.

Since detailed information on the geology and occurrence of ground water is not available, specific statements on the adequacy of the supply cannot be made. In general, the conditions stated for the Ahtanum Valley--that withdrawals from shallow depths will have to be considered in light of possible effects on surface supplies--applies to the entire Basin.

The ground water supply appears to be adequate to meet municipal needs and it is probable that ground water will continue to supply the needs of at least the smaller municipalities, since it is usually less expensive to drill the relatively deep wells required rather than construct and operate water treatment plants. Because of the depth of wells required to obtain adequate supplies without affecting surface water supplies, it is doubtful that extensive new irrigation development will depend on ground water.

B. Ground Water Quality

In general, ground waters can be expected to be more highly mineralized than surface waters. This is the result of dissolving and leaching from the soil of chemical constituents as the water percolates downward to the aquifer. The chemical make-up of the formation through which the water passes will be reflected in the chemical make-up of the ground water. Shallow ground water such as is found in the alluvial areas in the Yakima Valley will also reflect the factors causing changes in water quality which take place immediately above or adjacent to the point of measurement. Ground water withdrawn from shallow wells near surface waters will be similar to the surface water in quality. The quality of shallow ground water will also be affected by irrigation, septic tank drainage, etc.

Water from deep formations such as from the basalt formation in the Ahtanum Valley in most cases travels long distances and is not usually susceptible to localized effects from irrigation, septic tanks, etc. Bacterial contamination of shallow wells in some suburbs of Yakima has been reported by the Yakima County Health Department.

Chemical analyses have been run by the U. S. Geological Survey on seven wells in the Ahtanum Valley and in addition field determinations of hardness and chloride were made on 37 additional wells. These analyses showed a range in hardness from 49 to 265 mg/l and a chloride concentration range of 0.7 to 26 mg/l. The breakdown by formation is as follows:

	No. of Samples	Cl (ppm)	Hardness as $CaCO_3$
Yakima basalt	6	1.2-8	54-95
Ellensburg formation	9	6-26	75-240
Cemented gravel	10	5-26	120-265
Unconsolidated alluvium	19	0.7-14	49-148

More chemical analyses for the seven wells are listed in Table 3 of the Appendix. It has been found that the concentration of various chemical constituents is related much more closely to the rock material in which the water occurs than to the depth or geographic location of the well. Water from the basalt is generally lower in chloride and hardness concentration than water from other aquifers and the hardness of water in the shallow alluvial formations increases in the down-valley direction. Some wells tapping the basalt aquifer reportedly contain small amounts of hydrogen sulfide.

Complete chemical analyses were run on seven groundwater supplies in the Wenas Creek Valley and hardness and chloride determinations made on 48 additional samples. These tests showed a range in hardness from 55 mg/1 to 360 mg/1. Water from the basalt had the lowest average hardness and that from the upper Ellensburg formation the highest. The chloride concentration varied from 1.8 to 54 mg/1. Table 3 of the Appendix lists complete chemical analyses for 27 ground water supplies in the Yakima Basin, including the detailed analyses from the Ahtanum and Wenas Valleys.

Ground water is in most cases more highly mineralized than the surface water in the Basin. Dissolved solids, a good indicator of mineralization, averaged 135 mg/l at Kiona and reached a maximum of 236 mg/l at that point. Table 3 shows that 24 of the wells had a dissolved solids content more than 135 and that 10 had a reading higher than 236. There appears to be a relatively general increase in the common cations (positive) and that in most cases bicarbonate and chloride ion concentrations were higher than the average concentration at Kiona but that the sulfate concentration was more often lower. Silica concentrations were almost always higher than those normally found in the surface waters. Only about one-quarter of the samples showed water than would be classified as hard (over 150 mg/l as $CaCO_3$) while the remainder was soft or moderately hard. The dissolved solids concentration exceeded the Drinking Water Standards recommended maximum of 500 in only one instance. Other chemical constituents were well within the Standards. The ground water can, therefore, be considered as good to adequate for domestic purposes from a physical and chemical standpoint. The hardness of several of the waters is high enough to make softening economically justifiable. The bacterial quality of the deep wells is good and, in all cases of municipal use, chlorination is the only treatment required. Waters withdrawn from shallow formations, especially in built-up areas utilizing septic tanks as a means of sewage disposal, are subject to bacterial contamination. The Yakima County Health Department

reports shallow wells with a degree of bacterial contamination in the area surrounding Yakima. State Health Department figures through 1950 show a higher incidence of enteric diseases such as typhoid fever, paratyphoid fever, dysentary, diarrhea, and enteritis in Yakima County than in the remainder of the State. The data further show that the incidence of these diseases is higher in the rural areas of the county than in the City of Yakima. Drinking polluted water is often the cause of these enteric diseases and, thus, it is probable that the use of unchlorinated water from shallow wells by rural households contributes to the relatively high incidence of enteric diseases. From this information, it must be concluded that the bacterial quality of shallow ground water supplies in built-up areas and where irrigation causes a marked increase in the water level should be highly suspect, and disinfection should be practiced by all users.

In general, the quality of ground waters in the Basin is adequate for the majority of the Basin's industrial uses, such as cooling and washing. Ground waters to be used in all but low pressure boilers should be softened and the silica content reduced to prevent excessive scaling.

The ground water appears to be completely adequate for irrigation use.

IV. SURFACE WATER QUALITY

This section of the report attempts to present water quality data in a readily usable, clear, and concise manner. The data used in this section were collected by a number of agencies for a number of different purposes. The available data are explained and an interpretation of the quality of the water for various purposes is made.

A. Water Quality Data Collection Programs

The cooperative U. S. Geological Survey-Washington Pollution Control Commission program for the collection of water quality data has been in operation since approximately July 1, 1959. Yakima River samples are collected daily at Kiona and Parker and composited over a one to four week period and analyzed for physical and chemical constituents by the U. S. Geological Survey. Samples are collected once each month on the Yakima River at Cle Elum and on the Naches River near its confluence with the Yakima River. Determination of chemical and physical constituent concentration is also made on these samples. The monthly samples are analyzed by the Pollution Control Commission for dissolved oxygen and coliform MPN.

The U. S. Geological Survey began collecting water quality data in the Basin before the cooperative working arrangement with the Washington Pollution Control Commission was established. Daily samples composited over one to four week periods and analyzed for chemical and physical characteristics were collected during the

period January 1953 to September 1956 for Cle Elum and December 1952 until June 1959 at Kiona.

A sampling station near the mouth of the Yakima River was established by the Public Health Service in the spring of 1961 as part of its National Water Quality Network. Physical and chemical analyses are made on grab samples collected weekly. In addition, coliform MPN's and radioactivity samples are collected weekly and sent to the Robert A. Taft Sanitary Engineering Center in Cincinnati for analysis. Semi-monthly samples are collected and sent to Cincinnati for determination number and types of algal organisms and other plankton. A carbon filter is also in operation at the Richland station. Some 4,000 to 5,000 gallons of water are filtered through the carbon filter each month. Approximately once a month, the filter is changed; the used filter being sent to the Sanitary Engineering Center for the removal and analysis of material contained in the filter. Examination of this material reveals something of the extent and nature of various groups of pollutants including such material as organic pesticides.

Several agencies have collected water quality data in the Yakima Basin for the purpose of answering specific questions. These surveys were often short term, intensive investigations in which water quality at a fairly large number of points was examined. The most notable of these was the survey conducted by the Washington Pollution Control Commission in the summer of 1951. Eighty-three stations were sampled

six to twelve times each, and up to thirteen different tests were performed on each sample. Professor R. O. Sylvester conducted the 1951 survey for the Pollution Control Commission and, during 1954, 1955, and 1956, collected samples throughout the Columbia River Basin including the Yakima Basin to assess water quality conditions for the U. S. Fish and Wildlife Service. Professor Sylvester received a Public Health Service research grant to study the relationships of agricultural practices and water quality; and he and graduate students have collected a considerable amount of data and written two papers on the irrigation return flows, their effect on water quality, character, etc. (Unpublished Master's Thesis by Fred Poe and "The Character and Significance of Irrigation Return Flows in the Yakima River Basin".)

The Public Health Service and Washington Pollution Control Commission conducted an intensive three-day sampling program during critical flow conditions in September of 1961. A subsequent and less extensive study was made in February 1962.

B. Factors Affecting Water Quality

Water quality in the upper reaches of the river system is very high. Surface water is generated mainly from snow melt and there is very little human development in the area. The uppermost point of the river system receiving wastes is at Ronald on the Cle Elum River. From this point downstream to the mouth, the Yakima River and its tributaries receive periodic discharges of municipal and industrial wastes as well as drainage from irrigated agricultural areas.

Twenty-seven communities in the Basin have sewerage systems serving approximately 120,000 people. Each of these communities, with the exception of Renald, Roslyn, South Cle Elum and West Richland, have at least primary treatment plants, and the majority (nineteen) have intermediate or secondary plants. Seventeen of the treatment plants are listed by the Washington Pollution Control Commission as having adequate treatment facilities, while ten need expansion or improvement.

It is difficult to assign a population equivalent to the industrial waste load reaching the Yakima River system because of the wide seasonal variation in industrial activities and waste treatment practice. The largest industrial waste production occurs during the fruit and vegetable canning season in the late summer months, but treatment by land disposal and lagoons with little or no overflow reduce discharges of these wastes to watercourses to a bare minimum. During winter months, a number of food processing plants such as a sugar refinery, apple and potato processers, vinegar makers, etc., are in operation. Land disposal cannot be practiced during the winter months and lagoon overflow is increased by the excess of precipitation over evaporation. The net effect is a considerably greater stream loading during the winter months than during summer months. Because of greater stream flows and lower temperatures, the effect on the river is, however, less severe during winter months.

During the summer months when the majority of wastes entering the river system are from domestic and commercial sources, the population equivalent discharged is in the neighborhood of 55,000 to 60,000. The wintertime population equivalent reaching the river probably reaches a maximum of over 200,000. There will, of course, be transition periods where waste loading to the stream will be at some intermediate value.

Return irrigation flow contributes to the degradation of the Yakima River waters by increasing the concentration of dissolved and suspended material in the stream. There are some 600,000 potentially irrigable acres in the Yakima Basin of which 400,000 to 450,000 are presently irrigated. Yakima River water is reused for irrigation several times in its passage downstream; the mineral content being increased each time as material is leached out of and dissolved from the soil and evaporation and transpiration. The majority of the irrigation return flow enters the river in the reach between Yakima and Prosser.

C. Water Quality Parameters

1. Common Mineral Ions

The most abundant chemical materials found in the Yakima River and most other natural waters are bicarbonate, chloride, sulfate, calcium, magnesium, sodium, and potassium ions. In the upper portion of the Yakima Basin, the concentration of these common ions is very low and the concentration remains fairly constant throughout the

year during varying flows in the river. As the stream flows toward its confluence with the Columbia River, the concentration of these ions is increased by the addition of wastes and, more importantly, by waters which have been used for irrigation. Figure 3 shows the type of relationship that exists between the concentration of the common ions and flow for the upper portion of the basin at Cle Elum and the lower portion at Kiona. The increasingly greater concentrations of the common ions at Kiona as the flow is reduced is the result of the lack of high quality water to dilute the more highly mineralized wastes from cities, industries, and most importantly, irrigated areas. Figure 4 shows how the concentration of the common ions increases in the downstream direction during the late summer months. Note the rapid increase between Zillah and Prosser, the reach which receives the major portion of irrigation return drainage.

The following sections present a discussion of each of the common ions.

a. Chloride

Chloride ion can be an important consideration in selecting a water supply since it imparts a salty taste when present in a sufficient concentration. Sources of chloride in water include natural rock and soil formations and domestic and industrial wastes.

The Drinking Water Standards recommend a maximum of 250 mg/l of chloride in drinking water; however, water supplies with a concentration of over 1,000 mg/l have been utilized without apparent ill effect when necessary.

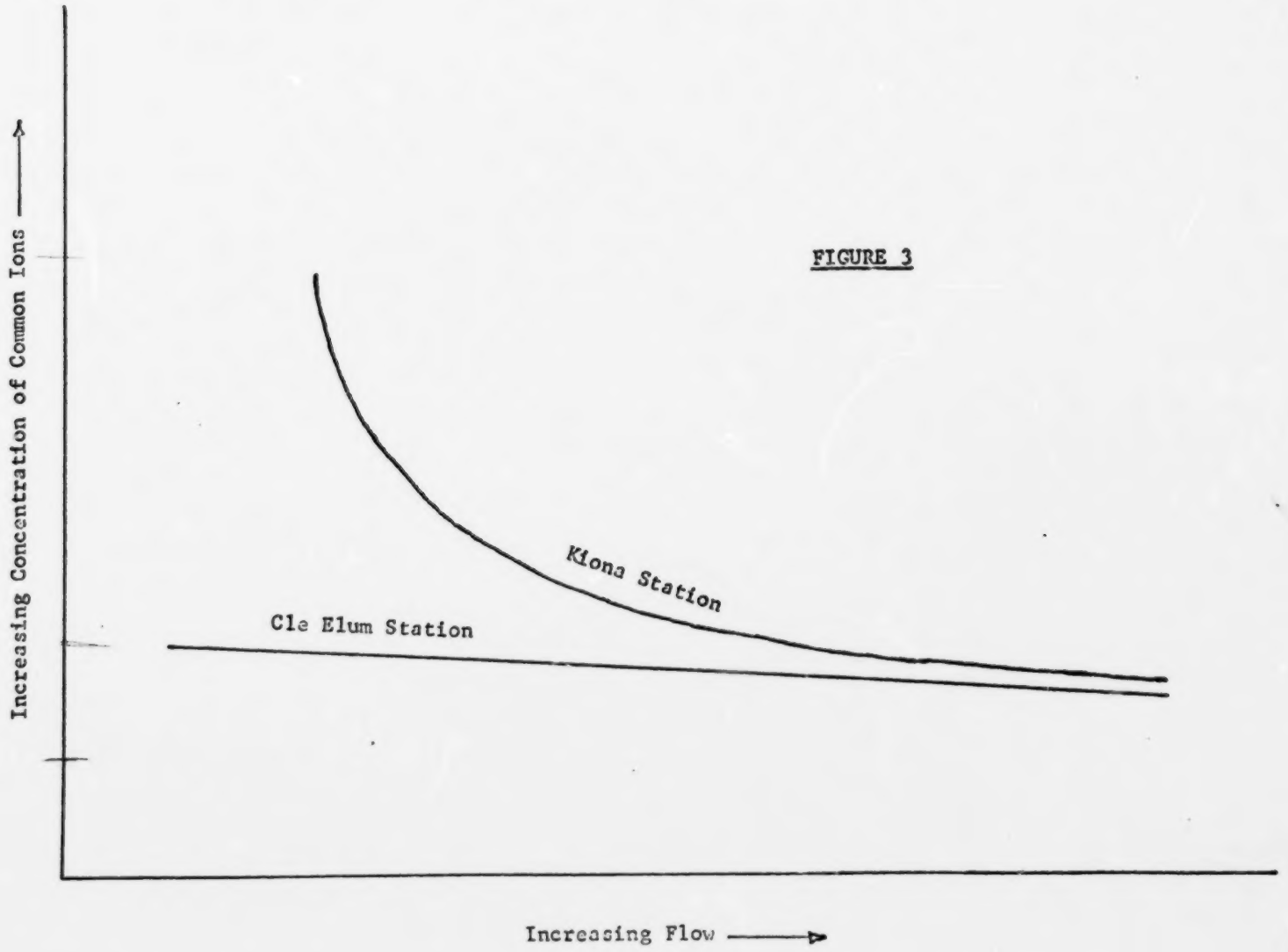
Increasing Concentration of Common Ions
Kiona Station
Cle Elum Station
Increasing Flow

FIGURE 3

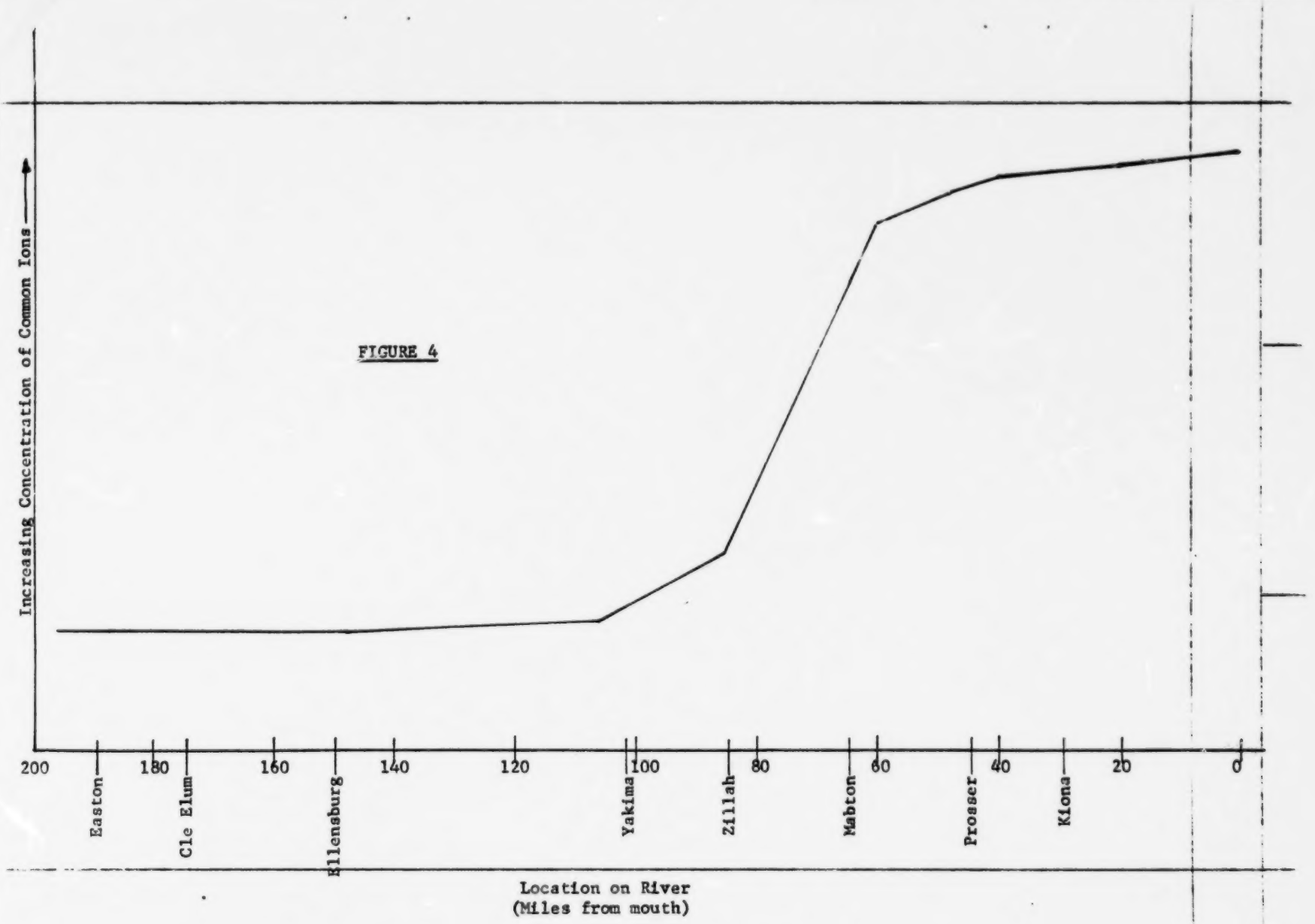
Increasing Concentration of Common Ions
200
180
160
140
120
100
80
60
40
20
0
Easton
Cle Elum
Ellensburg
Yakima
Zillah
Mabton
Prosser
Kiona
Location on River
(Miles from mouth)

FIGURE 4

Chloride ion concentration in the Yakima River ranges from an average of approximately 1 mg/l at Cle Elum and at the mouth of the Naches to approximately 2 mg/l at Parker and 4.5 at Kiona. It should be noted that the greatest increase takes place in the reach below Yakima. Domestic sewage usually increases the chloride content of the carrying water by approximately 15 mg/l. Considering the background chloride concentration and the amount of sewage entering the Yakima River in comparison with the river discharge, it must be concluded that domestic sewage is not the principal contributing factor. Individual samples of irrigation return water showed chloride concentration ranging from 2 to over 30 mg/l, thus indicating that the major chloride contribution is from irrigation return flow.

It is apparent that Yakima River waters are well within the limits set for high quality drinking water and, additionally, all but possibly a very few industries would find the water of satisfactory quality with respect to chloride ion content.

b. Hardness, Calcium, and Magnesium

Waters with hardness in the range of zero to 50 or 75 mg/l are generally considered "soft", while those with a hardness of 75 to 150 are considered "moderately hard". Hard water requires the use of more soap than soft waters and, in addition, hard waters may leave a scale deposit on hot water pipes, water heaters, boilers, etc. In addition, hard waters may interfere with industrial processes

such as food processing and some manufacturing processes. High pressure boiler water must be especially soft to prevent scaling.

Hardness (expressed as calcium carbonate) due to calcium and magnesium in the Yakima River increases from an average of 22 mg/l at Cle Elum to approximately 45 mg/l at Parker and 76 mg/l at Kiona. It should be noted that the increase in hardness between Cle Elum and Parker, a distance of 76 river miles, is less than the increase between Parker and Kiona, which are only 68 miles apart. This condition is due to dilution by the soft (26 ppm) Naches River water above Parker and to the drainage into the river below Parker of hard water. Hardness in the lower portion of the river increases greatly as the flow decreases. This can be explained by the fact that, during high flows, the runoff is mainly from the ground surface and consequently there is little time for the water to dissolve calcium, magnesium, and other hardness-producing minerals from the soil.

	Hardness			Calcium			Magnesium		
	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Cle Elum	22		35		4.6	9.5		0.8	3.4
Parker	45		70		7.0	16		1.8	5.8
Kiona	76		145		11	25		3.2	14

The hardness of Yakima River water in the upper portion of the Basin is low enough that all but a few industries would find the water satisfactory without softening. Water in the lower portion of

the Basin during low flow conditions would require softening by several types of industries. The water in all portions of the river would be adequate for domestic use without softening.

c. Sulfates

Sulfate ion is one of the most common anions (vegetative) found in surface waters. It is commonly dissolved from soil and rock formations by ground and surface waters. When present in a sufficient concentration in drinking water, sulfate ion has a cathartic effect on humans. The Drinking Water Standards recommend a maximum of 250 mg/l when better supplies are available; however, drinking water with a sulfate content of several hundred parts per million has been used without apparent damage to health. Waters containing appreciable amounts of sulfates tend to form hard scales in boilers, thus reducing the value of such water for many industrial purposes.

The sulfate content of Yakima River water is well below the 250 mg/l recommended drinking water limit. The average concentration varies from approximately 2.0 mg/l at Cle Elum to about 4 at Parker and approximately 12 at Kiona. The relatively large increase below Parker can be attributed to the discharge of relatively high sulfate content water from small streams and irrigation return drains. The sulfate content of some of these discharges may average over 50 mg/l. The sulfate content of the Yakima River in the lower reaches varies widely with the flow; that is, it is higher

at low flow than at high flow. This does not hold true for the upper reaches of the river.

Sulfate concentrations are well below the levels considered undesirable for domestic and industrial purposes.

d. Sodium and Potassium.

Sodium and potassium are chemically similar and are widely distributed in the earth's crust. Consequently, they are commonly found in surface and ground waters.

The Drinking Water Standards do not specify maximum allowable concentrations of sodium or potassium. Excessive quantities of sodium in drinking water may be harmful to persons suffering from cardiac or circulatory ailments. New interest is being shown in the potassium content of water since an isotope (K^{40}) is radioactive and is an important contributor to background radiation. Sodium plus potassium concentrations above approximately 50 to 100 mg/l impair the usefulness of water for some industrial purposes. These concentrations cause foaming in boiler waters. Plants require small amounts of both sodium and potassium for proper growth, but in excessive concentrations they react with soil to reduce soil permeability.

Sodium and potassium concentrations in the Yakima River are quite low, The average concentration ranges from about 1.5 mg/l at Cle Elum to 5.5 mg/l at Parker at 15 mg/l at Kiona. Again, the greater increase in the lower reaches must be attributed to irrigation

return flow and the more highly mineralized creeks in that area. The sodium concentration in these drains at times reaches 50 to 60 mg/l of sodium. The average potassium concentration varies from 0.5 mg/l at Cle Elum to 1.5 at Parker and 3 at Kiona, with maximum of about 10 mg/l occuring in irrigation return drains. It is apparent that these concentrations are well below the levels associated with boiler water forming and other industrial limitations.

The sodium content of irrigation waters is usually expressed as either the percent sodium 1/ or the sodium absorbtion ratio. 2/ The percent sodium value average 16 and 26 at Cle Elum and Kiona, respectively, and the sodium absorbed ratio average 0.2 and 0.6 at these two stations. One source 3/ indicates that water with a percent sodium less than 20 be rated as "excellent" and water with a percent sodium of 20-40 be rated as "good". Using the sodium absorbed ratio, the same source indicates that water with an SAR less than 10 be rated excellent. From these guides, it can be seen that Yakima River water is highly satisfactory for irrigation purposes.

2. Other Chemical Parameters

The chemical parameters discussed in the following section are more difficult to discuss as a group than the common ions described

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1/ $\% \text{ Na} = \frac{(\text{Na} + \text{K})\ 100}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}}$ (all in meq/l)

2/ $\text{SAR} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}}$ (all in meq/l)

3/ Ground Water Hydrology, David K. Todd, 1959.

in the previous section. The appropriate chemicals will, therefore, be discussed individually and appropriate figures and tables used where needed.

a. Alkalinity

The alkalinity of water is defined as its capacity to neutralize acid. Alkalinity in natural water is usually due to carbonate ($CO_3^{=}$), bicarbonate (HCO_3^{-}), hydroxide (OH^{-}) ions and occasionally to borate, silicate and phosphate ions and organic substances. Bicarbonate represents the major form of alkalinity and is derived naturally from the action of carbon dioxide on the carbonates of calcium and magnesium such as limestone, dolormite, magnesite, etc. Wastes added to a stream may also increase the alkalinity. The relative proportions of bicarbonate, carbonate, and hydroxide alkalinity that exist in a certain water are dependent upon the pH and, to a lesser extent, on the temperature of the water. At a pH less than 8.3, there will be only small concentrations of carbonate and OH^{-}.

The alkalinity of water has little direct effect on the value of the water but may have a secondary effect in that high alkalinities will increase the dissolved solids. The 1946 Drinking Water Standards set recommended limits for the various forms of alkalinity in finished water, but these limits have been omitted in the 1962 edition.

Total alkalinities (expressed as mg/l of calcium carbonated) in excess of approximately 50 to 100 limit the use of water for some industrial purposes such as certain food and beverage production operations. 1/

The U. S. Geological Survey measures the carbonate and bicarbonate ion concentration at Cle Elum, Parker and Kiona on the Yakima River. Average concentration of bicarbonate ion were 29, 58 and 100 mg/l, respectively, at these points, while the presence of carbonate ion was detected very rarely. In sanitary engineering practice, it is common to express alkalinity as mg/l of calcium carbonate. In this case, the bicarbonate alkalinity, and since there is no carbonate alkalinity or hydroxide alkalinity, the total alkalinity is equal to the bicarbonate ion concentration divided by 1.22. Thus, the total alkalinity at Cle Elum, Parker and Kiona averages 24, 48, and 82 mg/l as $CaCO_3$. The alkalinity of the Naches River at its confluence with the Yakima averaged approximately 30 mg/l (as $CaCO_3$)--approximately the same as the Yakima River at Cle Elum.

Alkalinity values are low enough throughout most of the Yakima River so as to not limit the majority of uses of the water.

Bicarbonate Ion Concentrations

	Average	Minimum	Maximum
Cle Elum	29	23	46
Parker	58	39	87
Kiona	100	57	195

1/Water Quality Criteria, California Water Pollution Control Board.

b. Fluoride

Fluorine is a highly reactive element which exists in nature as fluoride ion. Fluoride ion is found in many types of rock and soil, and it is from these materials that fluoride finds its way into surface and ground water.

The presence of approximately 1.0 mg/l of fluoride ion in drinking water has been shown to significantly reduce the incidence of dental caries in humans. However, as the concentration of fluoride increases above 1.5 mg/l, increased incidence of tooth disfiguration in the nature of mottled enamel (dental fluorosis) is detected.

U. S. Geological Survey records of fluoride content at Cle Elum and Kiona and the Washington Pollution Control Commission records for the Parker station indicate a relatively constant value of 0.1 mg/l with occasional readings of 0.0, 0.2 and 0.3 mg/l. These levels are too low to be significant benefit for the reduction of dental caries.

c. Hydrogen Ion Concentration

The pH of Yakima River water tends to be raised by soluble carbonates originating in the soil and by the photosynthetic activities of algae. The pH tends to be lowered by dilution from low pH surface water and by the absorbtion of carbon dioxide emanating from decomposing organic matter.

The desirable pH of water depends greatly upon the use intended for the water. Stream water with a pH in the range of 6.5 to 8.5 is generally considered normal and satisfactory. A pH range of 6.0 to 9.0 is not uncommon.

Maximum and minimum pH values noted in available data for the Yakima River during the past five years were 6.1 at Cle Elum in August 1961 and 8.9 at West Richland during the summer. pH values at any station vary with the seasons of the year, stream flow and time of day. There is, however, a detectable increase in pH as the stream flows toward the Columbia, the average summer pH at the mouth of the river being approximately ten percent higher than at Cle Elum. This increase can be attributed to the increasing presence in the stream of alkaline materials leached from the soil and to the increasing algal population as the mouth of the river is approached. Algal growth is especially dependent on phosphates and nitrates, both of which show a significant downstream increase. A measure of the effect of algal activity on pH can be obtained by comparing the values measured in daylight with those measured at night. During daylight hours, algae utilize carbon dioxide in the water and produce oxygen, the process being reversed at night.

Data obtained by Professor Sylvester during the summer of 1951 show that daytime pH's exceed nighttime pH's by as much as 0.8 in the reach just below Yakima.

The pH data available are generally not sufficiently complete to confidently identify the effects of any one waste source on the stream. The 1951 and 1961 data do show a sharp drop in pH at Yakima with a rapid recovery. This may be attributed to dilution by Naches River water, to carbon dioxide released in the decomposition of organic matter discharged in the area, or to a combination of the two.

pH values found in the Yakima River are in a range which is satisfactory for most uses.

d. Iron and Manganese

Iron and manganese are undesirable in water supplies used for domestic and many industrial purposes because they discolor material coming in contact with the water and may cause taste and odor problems.

The 1961 Drinking Water Standards recommend a maximum of 0.3 mg/l and 0.05 mg/l for iron and manganese, respectively.

The recommended minimum iron concentration for many industries, including food processing, is in the 0.1 to 0.2 mg/l range.

The iron concentration of Yakima River water is measured periodically at the cooperative U. S. Geological Survey-Washington Pollution Control Commission sampling station. The average concentrations have been generally below 0.05 mg/l with a maximum of 0.32 mg/l reported on one occasion. A very small number of samples were

analysed for manganese by Professor Sylvester in the 1954-1956 period. No manganese was detected in these tests.

Iron and manganese levels are sufficiently low so as to not impair legitimate water use.

e. Nitrate

The decomposition of organic material containing nitrogen proceeds through several steps including ammonia nitrogen (NH_3), nitrite nitrogen (NO_2), and nitrate nitrogen (NO_3) with liberation of nitrogen gas (N_2) under some conditions. This cycle may proceed partially in reverse order when no free oxygen is present (anaerobic conditions). Analytical methods are available to measure each of these constituents. Unless a detailed study of a water sample is being made, the usual practice is to measure only one or possibly two of the compounds in the nitrogen cycle. Nitrate is most commonly measured on a routine basis. Nitrate is the end product of the nitrogen cycle and is the form which can readily be used by most plants as a nutrient in their growth. Since it is the final product of the cycle, its relative abundance compared to other forms of nitrogen tells something of the "age" of the pollution.

Nitrates found in surface and ground waters are most frequently the result of the decomposition of organic material; either naturally occurring organic material, such as decaying vegetation, or sewage and industrial waste. Another source of nitrates in surface and ground waters and one which is of special interest in the Yakima

Basin is from fertilizers applied to the land for agricultural purposes. Many of these fertilizers contain nitrates for quick utilization by agricultural plants.

Excessive concentrations of nitrate in drinking water have been associated with the occurrence of methemoglobinemia in infants. The U. S. Public Health Service Drinking Water Standards, therefore, limit the allowable nitrate concentration in drinking water to 45 mg/l (as NO_3) or approximately 10 mg/l as N. Much lower concentrations of nitrate in combination with phosphate and other necessary materials stimulate the growth of algae and other aquatic plants to such an extent that they become a nuisance.

The average nitrate concentration in the Yakima River increased from approximately 0.1 mg/l (as N) in the Easton-Cle Elum area to approximately 0.2 mg/l in the Yakima area. The average concentration at Kiona is approximately 0.4 mg/l. Data collected during September, 1961 show concentrations close to those stated above for stations from Zillah upstream but show a sharp increase below Zillah to a maximum of approximately 2.5 mg/l (as N) at Kiona. Irrigation return drains discharging to the river below Zillah have shown nitrate concentrations as high as 6.0 mg/l.

These data indicate that irrigation return flow contributes the major portion of the nitrate load to the river and that municipal and industrial wastes discharged in the Yakima area are of relatively less importance as far as nitrates are concerned.

The nitrate concentration in the Yakima River is well below the level considered dangerous to public health and would interfere with few industrial processes. The concentration is, however, adequate to support a profuse aquatic growth.

f. Oxygen

The dissolved oxygen concentration of a stream is influenced by (1) the organic load and consequent use of dissolved oxygen in decomposition of the organic material; (2) the width-depth relationship and turbulence which governs its physical reaeration capacity; (3) water temperature which limits the amount of oxygen which will remain in solution and, further, governs the rate of decomposition; (4) the algal population since algae produce an excess of oxygen during daylight hours and require oxygen during darkness; (5) turbidity since the presence of turbidity reduces the transmittance of light and thus reduces the algal activity.

The threshold concentrations of dissolved oxygen at which fish and other forms of aquatic life are adversely affected varies widely with species, age, water temperature, presence of other material in the water, etc. Generally speaking, the more desirable game fish such as salmon and trout require higher oxygen concentrations than do scrap fish such as suckers, tench, bullheads, etc. It is the opinion of many that concentrations below approximately 6.0 mg/l are at least potentially detrimental to game fishes. In many eastern and midwestern areas, an objective of 5 mg/l minimum dissolved

oxygen has been set. In the western part of the country, a 6 mg/l minimum is more often the objective.

Minimum dissolved oxygen values in the Yakima River above Ellensburg range from approximately 7.5 to 9.0 mg/l during the critical summer months. These values correspond to 75-90 percent of saturation. Average summer daytime concentrations are in the range of 9.0 to 10.0 mg/l with saturation values of 90 to 100 percent. These values present a picture of essentially unpolluted water with only a small amount of oxygen demanding organic matter, probably naturally occurring aquatic life and little stimulation of algal growth by nutrients and fertilizers which would tend to give super-saturated conditions during daylight hours. Dissolved oxygen data collected in September 1961 show a drop of approximately 0.7 mg/l in the minimum reading just below the point where Wilson Creek discharges to the Yakima River. In its travel from Wilson Creek to the sampling station at Selah Gap, the dissolved oxygen concentration recovered to a level approaching that in the River above Ellensubrg. Nighttime dissolved oxygen concentrations in the Yakima River below the City of Yakima dropped progressively to a low point at Granger where a minimum reading of 6.5 mg/l was observed. In this same reach of the river, a general increase in the average daytime dissolved concentration was noted. These conditions are the same as were observed by the Washington Pollution Control Commission in their survey during the summer of 1951, except that a low of 5.5 mg/l was observed at Granger.

Below Granger, the dissolved oxygen concentration recovers to a level where minimum values are again in the range of 8 to 9 mg/l. Daytime values remain high, especially in the area below Prosser where readings of over 150 percent of saturation have been observed during summer months.

Generally speaking, the minimum dissolved oxygen values observed in the Yakima River are satisfactory to sustain nearly all types of aquatic life. The minimum values do, however, approach potentially harmful levels.

g. Phosphates

Phosphorous is present in inorganic compounds and, to a lesser extent, in organic compounds in wastes and receiving waters. The inorganic compounds of interest in water quality consideration are the orthophosphates and the polyphosphates; the latter being molecularly dehydrated and capable of being reverted back to orthophosphates in water. When examining water quality data, care must be taken to determine the form of phosphorous being measured (ortho-, poly-, or the combination of both) and whether or not the phosphorous in suspended matter is included.

Major sources of phosphates in streams are domestic and industrial wastes and runoff from land areas rich in phosphates. The increased use of synthetic detergents in the last few years has increased the amount of phosphorous in domestic sewage since many of these detergents contain a large amount of phosphorous. Runoff from

agricultural areas fertilized by compounds containing phosphorous may be rich in phosphates.

The occurrence of phosphorous compounds in wastes and receiving waters is receiving increased attention as their role in the production of algal blooms becomes better understood. Research has shown that blooms do not occur when sufficient nitrogen and phosphorous are not present. The concentration of phosphorous below which algal blooms do not occur has been established as approximately 0.01 mg/l

Soluble orthophosphates measured as phosphate ($PO_4^{=}$) range from .001 or .002 mg/l in the Easton area to 0.05 - .10 mg/l in the Yakima area. In the reach of the river between Zillah and Mabton, the phosphate concentration during the irrigation season increases rapidly to a level of 0.2 to 0.25 mg/l; then remains fairly constant at that level to the mouth of the river. Work by Professor Sylvester indicates that the combination of orthophosphates in solution and suspension may be two to three times higher than soluble phosphate alone for water in the lower reaches of the river. This can be attributed to the uptake of soluble phosphorous by aquatic organisms.

Sampling conducted in the Fall of 1961 shows that the soluble orthophosphate level increases gradually from the headwaters down to Zillah, increases rapidly between Zillah and Mabton, then declines slightly between Mabton and the mouth of the river. This shows

quite clearly that irrigation return flows contribute the major portion of the phosphates since most of the irrigation return drain discharge to the river between Zillah and Mabton. The slight decline at the lower end of the river can be attributed to the uptake of soluble phosphorous by aquatic organisms.

The phosphate concentrations found in the Yakima River are below levels known to be harmful for domestic and industrial use. The concentration in the lower reaches of the river is, however, high enough to support large plankton populations.

h. Silica

Silica (SiO_2) is present in natural surface water in concentration ranging from 5 to over 50 mg/l. Silica is suspended or dissolved in water as the water percolates through or otherwise comes in contact with such materials as silica sands and quartz.

The Drinking Water Standards do not limit the concentration of silica permitted in water supplies. Silica is, however, detrimental to certain industrial processes. Silica is particularly undesirable in boiler feed waters, since it forms deposits in piping and on turbine blades. Silica is a necessary constituent in some aquatic organisms, especially diatoms where the compound is used in the skeletal structure.[1/]

1/ J.M.

Recommended maximum silica concentrations for boiler feed waters [1/] range from 1 mg/l for boilers operated at 400 psi and over to 40 mg/l for low pressure boilers. Some pulp and paper making processes require maximum silica concentrations of 20 mg/l.[1/]

Data on silica concentrations in the Yakima River are available for three years at Cle Elum and Kiona and for one year at Parker. Average concentrations were 8 mg/l at Cle Elum, 15 mg/l at Parker and 25 mg/l at Kiona. Extremes were a low of 5.0 at Cle Elum and a high of 39 mg/l at Kiona. As with other mineral constituents in the Yakima River, the concentrations of silica tend to vary inversely with the flow.

3. Physical Parameters

a. Color

The term "color" refers to the color of the water after suspended solids have been removed. Natural color may be imparted to water in its contact with organic debris such as leaves, conifer needles and decaying wood or by some iron compounds. Certain industrial wastes such as textile dyeing and wood pulping wastes also impart color to water.

The presence of natural color in water has little sanitary significance. However, highly colored drinking waters are undesirable from the aesthetic standpoint and, further, some industrial processes require water with a low color content.

1/ Water Quality Criteria, California Water Pollution Control Board.

Incomplete color data for the Yakima show that color increases from an average of approximately 5 ppm at Cle Elum to an average of 15-20 ppm in the lower reaches of the river. A reading of 40 ppm was noted at Enterprise while maxima in upstream stations were in the 20-25 ppm range. The lack of data precludes an analysis to determine the relationship between color and streamflow, season, etc.

b. Solids

There are several designations of "solids" depending upon the analytical method used in making the determination. Total solids (also referred to as "total residue") is the term applied to the material remaining in a vessel after all water has been evaporated and the material dried at a certain temperature. This material contains minerals and other compounds whic h were formerly dissolved as well as silt particles, plankton, etc., which were in a suspended state. The temperature at which the residue is dried will affect the weight of the residue by: (1) varying degrees of volatization of of organic matter, (2) varying degrees of evaporation of chemically combined water, and (3) chemical changes such as liberation or combination of gases brought about by the heating. Common drying temperatures are 104 and 180 degrees Centigrade.

Total solids are often broken down to suspended solids and dissolved solids (filtrable and non-filtrable residue). The basis of this breakdown is a filtration process, the filter being

a crucible or filter paper. The material retained on the filter after evaporation and drying is the suspended or non-filtrable residue, while that passing through the filter is termed dissolved solids or non-filtrable residue upon evaporation and drying. In addition to the analytical limitations described for solids, the filtration step adds further limitations to the reproducibility of the results. The term dissolved solids is not strictly accurate because the classification includes colloidal matter not removed by the filter.

In addition to the classification mentioned above, there are fixed and volatile solids which indicate the relative abundance of inorganic and organic material. Settleable solids, used most frequently with regard to wastes, indicates the amounts of solid material which will settle from suspension in a prescribed time.

The U. S. Public Health Service Drinking Water Standards recommend that the concentration of dissolved solids in drinking water not exceed 500 mg/l. Water with concentrations somewhat higher than this are used where higher quality water is not available. Waters with a very high (well in excess of 500 mg/l) dissolved solids content may have a laxative effect on new users and, in general, will affect the palatability of the water. No lasting harmful physiological effects have been noted, however, from the use of waters with a high dissolved solids content.

Certain industrial processes including the manufacture of high grades of paper and textiles, and boiler feed water may require water with a dissolved solids concentration in the 50 to 200 mg/l range. Most other industrial processes can utilize waters of a high dissolved solids content.

The Drinking Water Standards do not set limits for suspended solids as such. However, suspended solids are related to turbidity and a high suspended solids concentration will produce a high turbidity. High suspended solids content, of course, affects the aesthetic quality of a drinking water and may cause a health hazard by entrapping, and thus insulating, pathogenic organisms from the effects of chlorine and increases the cost of water treatment by necessitating the construction of facilities to remove the suspended matter.

Excess concentrations of suspended solids are harmful to many industrial processes. Again, limiting values are almost always set in terms of turbidity rather than suspended solids.

Material settling from suspension in streams can have an adverse effect on aquatic life. The deposited material blankets bottom life, thus interrupting the food chain, and may cover and suffocate fish eggs and young. Excess quantities of material in suspension may also have a clogging and abrasive effect on the gills of fish.

Agencies collecting water quality data in the Yakima Basin measure different solids constituents, thus making a direct comparison of results difficult. Dissolved solids, evaporated and dried at 180 degrees Centigrade, are measured at the cooperative Washington Pollution Control Commission-U. S. Geological Survey sampling stations at Cle Elum, Parker, and Kiona. The average concentrations at these points are 35, 70 and 135 mg/l, respectively, with a maximum of 236 mg/l at Kiona and a minimum of 27 mg/l at Cle Elum. Samples collected during the summers of 1951 and 1961 were analyzed for total solids. The results of these surveys showed total solids concentrations (evaporated and dried at 103 degrees Centigrade) of 20 to 70 mg/l in the River above Yakima with a sharp rise to 300-350 mg/l in the reach below Yakima. Suspended solids accounted for less than ten percent of the total in most cases.

The sharp increase in total solids noted in the reach of the stream below Yakima can be attributed to municipal and industrial wastes discharged in the area and probably to a greater extent to irrigation return flow. No samples for total or suspended solids have been collected during periods of heavy runoff, but it could be expected that they would show a relatively larger portion of suspended material than during the dry summer months.

The solids content of Yakima River water is well below the level affecting its use as a source of domestic water, but in the lower reaches of the river, certain industries would find the solids concentration too high.

c. Temperature

Water temperature is an important consideration when assessing the sanitary quality of water. Although in the past not commonly considered as a "pollutant", high water temperatures can seriously impair the usefulness of the water for many purposes.

Temperature has an important effect on the biochemical activity in streams. Over the temperature range found in natural bodies of water, there is an approximate doubling of the biochemical activity with each ten degree Centigrade rise in temperature (van't Hoff rule). This means that organic wastes will be stabilized in a much shorter time in warm water than in cold water and that there will be a need for greater dissolved oxygen supply and/or reaeration capa city in a stream. It should be remembered too that the dissolved oxygen saturation value decreases as the temperature increases.

Most fish have optimum temperatures at which they live and grow best and beyond which they are harmed or killed. The limiting temperature beyond which salmon will either be killed or move to other waters appears to be approximately 75 degrees Fahrenheit. A temperature of 83 degrees Fahrenheit has been reported to be the upper limit for some trout species.[1/] Other fish, such as large mouth bass, pumpkin seed sunfish, and other species have been

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1/ Water Quality Criteria.

found alive and apparently in satisfactory condition in water at 89 degrees Fahrenheit.[1/]

High water temperatures tend to stimulate the growth of algae and other aquatic plants. Most species of algae have an optimum temperature for maximum growth and reproduction.

Temperature affects the suitability of water for drinking purposes. When the temperature exceeds 60-65 degrees F, the water is considered objectionable for drinking by most consumers.[1/] Many industrial processes have limiting temperatures requirements. Examples are: 55 degrees F. for barley malting, 60 degrees F. for many farms and dairy factors, and 75 degrees F., for use in steel mills.[1/] Water to be used for cooling should, of course, be as cool as possible for maximum beneficial use.

Records of daily water temperatures are available for Kiona, Cle Elum and Parker and, in addition, data gathered during the summer of 1955 in the lower Yakima valley is tabulated in the Appendix of this report. The four year average temperature at Cle Elum ranged from 35 degrees F. in January and February to 54 degrees F. in July. Extremes recorded during this period were 32 and 61 degrees. Six years of record at the Kiona station show the yearly average minimum of 37 degrees F. occurring in January and the average maximum of 73 degrees F. occurring in July. Extremes recorded were 32 degrees F. and 81 degrees F. Daily records are available for only ten months at the Parker station. These show a

minimum yearly average of 35 degrees F. in January and a maximum average of 61 degrees F. in June. Records are not available for July and August.

Recording thermographs were installed at three stations in the Lower Yakima Valley during the summer of 1955 to provide a continuous record of air and water temperatures. The stations were located at the Wapato-Donald Bridge (No. 1), the Chandler power drop below Prosser (No. 2), and at the mouth of the river (No. 3).

The purpose of the survey was to determine the effect of irrigation return flow on Yakima River water temperature and to attempt to correlate air and water temperatures. Station No. 1 is above the point where significant irrigation return flows reach the river, while Station No. 2 (and No. 3) is below major return flows. The flow time between Station Nos. 1 and 2 was approximately thirty-five hours, and between Nos. 2 and 3, nine hours. The data showed an average temperature increase of 14 degrees F. between Stations Nos. 1 and 2, and 1.5 degrees between Stations 2 and 3. The majority of the increase between Stations Nos. 1 and 2 was attributed to irrigation return flow warmed in the canals, ditches, and during its application to warm soil. A high correlation between air and water temperature was noted.

It is apparent that water temperatures in the lower Yakima River reach levels detrimental to several uses during the low flow-high air temperature period in the late summer.

d. Turbidity

Turbidity is caused by suspended organic and inorganic particles in water and is a measure of the light scattering or absorbing power of the solution. Turbidity is measured and reported in "turbidity units" rather than milligram per liter or parts per million, the units commonly used in water quality work.

Turbidity in streams may result from a wide variety of sources, including land erosion by surface runoff, stream bank erosion, municipal and industrial wastes, municipal street cleaning operations, etc. The sanitary significance of turbidity rests in its effect on ease of operation and efficiency of water treatment plants and the damage caused to aquatic life by the blanketing of stream beds with settled material.

The Drinking Water Standards turbidity in the finished water is to 5 turbidity units and a number of industrial users require water with a maximum turbidity of 1 to 20 units.

Turbidity values averaged approximately 2-5 in the Cle Elum area and 10-20 in the lower reaches of the river where a maximum of 110 was recorded. Values somewhat higher may occur during periods of rapid runoff.

The limited amount of turbidity data available for the Yakima indicates significantly higher turbidity values in the lower reach of the river as compared to the upper reaches. This is quite probably due mainly to surface runoff from farm lands. This

contention is further verified by the fact that higher than average turbidity values were recorded during rainy periods. The data show a poor correlation between stream discharges and turbidity. This may be explained by the fact that highest stream flows occur in the late spring and are due to snow melt in the high mountains where ground cover is adequate to prevent excessive erosion.

Turbidity concentrations are sufficiently high to require treatment for domestic and many industrial uses throughout most of main stem of the Yakima River.

4. Biological Parameters

a. Bacteria

The bacterial quality of water is most frequently gaged by the number of coliform bacteria found in a given volume of water. The coliform bacteria concentration in a water sample is usually expressed as the "most probable number" (MPN) per one hundred milliliters of the water.

The Public Health Service has published recommendations based on bacterial content concerning the degree of treatment that should be provided waters to be used for drinking. A summary of these recommendations is as follows:

Group I - Water Requiring No Treatment. Underground waters not subject to any possibility of contamination and meeting all requirements of the Drinking Water Standards.

Group II - Water Requiring Simple Chlorination or Its Equivalent. Underground and surface waters subject to a low degree of contamination where the coliform bacteria content averages not more than 50 per 100 ml in any month.

Group III - Waters Requiring Complete Rapid-Sand Filtration or Its Equivalent, Together with Continuous Postchlorination. All waters requiring filtration to remove turbidity, color, etc., and waters polluted by sewage to such an extent to be inadvisable to groups I and II. The coliform bacteria content should, however, not average more than 5,000 per ml in any one month. In addition, the 5,000 figure should not be exceeded in more than 20 percent of the samples in any month.

Group IV - Waters Requiring Auxiliary Treatment in Addition to Complete Filtration and Postchlorination. Waters meeting the requirements of Group III except that the coliform bacteria content exceeds 5,000 per 100 ml in more than 20 percent of the samples in a month. To meet Group III standards, the coliform content must not exceed 20,000 per 100 ml in more than 5 percent of the samples in any month.

Many industries, especially food processing industries, require water of bacterial quality equal to or higher than for drinking purposes. In addition to the health hazard in using waters

of unsatisfactory bacterial quality for food processing, economic losses caused by food spoilage would occur.

Uniform bacterial quality standards have not been developed for waters to be used for irrigation. In general, waters used to irrigate human foodstuffs, especially those to be eaten raw, should be of high quality. The State of Utah has developed a tentative standard of 5,000 coliform bacteria per 100 ml maximum for general irrigation.[1/]

Bacterial limits for natural bathing waters vary greatly in different parts of the country. The Pacific Northwest Pollution Control Council has developed a recommended limit of 240 coliform organisms per 100 ml for the Northwest. This limit is in general accepted by Pacific Northwest States.

Coliform bacteria concentrations are measured once a month at Cle Elum and Parker on the Yakima River and on the Naches River at Naches by the Washington Pollution Control Commission. Records for one year only are available. They show an average MPN per 100 ml of 125 at Cle Elum, 10,900 at Parker, and 660 at Naches with maxima of 930, 460,000 and 2,300, respectively. Results of summer surveys conducted during the summers of 1951 and 1961 corresponded closely and showed the coliform MPN increasing from approximately 100 per 100 ml at Easton to 2,500-4,000 below Ellensburg, then dropping to approximately 1,000 just above Yakima. Immediately below Yakima, the MPN jumped to 25,000-50,000 level, dropped back to

1,500-2,500 level, then fluctuated generally between 1,000 and 5,000 in the remainder of the stream.

The most striking feature of the data is the sharp increase in the MPN below the City of Yakima. Municipal wastes from the city are given primary treatment with chlorination. The high MPN below the city can be attributed to inadequate chlorination of the treatment plant effluent, the discharge of untreated domestic and industrial wastes to the river, or the combination of these factors. MPN's higher than the river MPN occur in a number of small streams or irrigation return drains in the lower Yakima valley. Most of the municipal wastes discharged to these watercourses are chlorinated and, again, the high MPN's can be attributed to inadequate chlorinating, untreated municipal and industrial wastes, and runoff from irrigated areas, livestock feeding areas, etc.

Complete treatment would be required for municipal and some industrial water supplies if the main stem of the Yakima River is to be used as a source of water.

b. Plankton

Heavy growths of plankton and higher forms are found in the Yakima River from Roza diversion dam to the mouth. The photosynthesis and respirational activities of these organisms cause a wide diurnal fluctuation in dissolved oxygen, pH, alkalinity, CO_2, etc., in the Yakima River. The abundance of such organisms causes nuisance problems which would be magnified greatly if the lower Yakima were ever to be used for water supply purposes. CRBP Working Paper No. 13 sets forth the results of certain biological investigations in the Basin.

V. INTERPRETATION OF WATER QUALITY DATA

A. Physical and Chemical Constituents

1. Irrigation and Industrial Use

The chemical quality of Yakima River water is satisfactory for the majority of industrial uses throughout the full length of the river. A number of industrial uses which require especially high quality water--such as high pressure boilers, certain products, etc.--would, however, require special treatment of the waters found in the lower reaches of the river. It seems that, in the absence of some other over-riding consideration, industries requiring high quality water would tend to locate in the upper portion of the basin or in some other basin with higher quality water. The dissolved solids concentrations of the Yakima River at Kiona average, for example, 29 percent higher than the Columbia below its confluence with the Yakima. Furthermore, the maximum yearly concentration averages some 56 percent higher.

2. Public Water Supply Use

The turbidity and color concentration which occur periodically in the Yakima River would make necessary treatment of the water for use in municipal systems in all but possibly the uppermost reaches of the river. The high temperature of water found in the lower reaches would, during the summer months, make the water objectionable for domestic use.

The concentration of chemical constituents that have been measured are within the requirements set forth in the PHS Drinking Water Standards throughout the full length of the river. Certain elements and compounds such as arsenic, barium, cadmium, chromium, copper, cyanide, lead, selinium, and silver have not been adequately measured to determine compliance with the Standards.

A secondary effect on municipal and, in some instances, industrial supplies resulting from the nitrate and phosphate concentrations in the river is a taste and odor problem caused by algae. It was noted earlier in the report that the concentration of these two key compounds is sufficient in the lower reaches of the river to produce sizable algae populations. These growths may well include species which generate taste and odor problems in the stream.

3. Fish Habitat

The dissolved oxygen content of the river has not been measured at levels which are known to be detrimental to fish life. Minimum values in the ranges of 5.5 to 6.5 mg/l have, however, been detected. This content is considered by some authorities to be at least potentially harmful. The effect on fish of relatively high temperatures, reaching a maximum of approximately 80 degrees F., should be of greater concern than the dissolved oxygen levels found in the Yakima River.

During the growing seasons, a variety of chemical substances are applied to lands in the Yakima Basin for such purposes as insect control in forests, insect and weed control on agricultural lands and weed control in irrigation return drains. Many of these chemicals are known to kill fish and organisms on which the fish feed at very low concentrations. The concentration of these materials is not known to damage aquatic life in the Yakima River, but with the rapid increase in the use of such pesticides in agriculture, it would seem that monitoring for these compounds would be advisable.

The largest factor affecting the fish habitat remains to be, however, the low flow situation occurring in certain headwater and main stem reaches.

4. Recreational and Aesthetic Value

The conditions of temperature, turbidity, and algal population found in the lower reaches of the Yakima River impair its recreational and aesthetic value during the summer months. Conditions are, however, very favorable to these values in the portion of the Basin above Yakima.

B. Biological Constituents

1. Industrial Use

The bacterial concentrations found in the Yakima River below Yakima would make necessary complete treatment including disinfection before the water would be usable for certain industries,

such as some food processing industries, requiring waters of high bacterial quality. Most industries would, however, find the bacterial quality, especially in the upper reaches, satisfactory for their use.

The usefulness of Yakima River water for industrial processes incorporating the water in a product could be impaired by tastes and odors produced by plankton growths during certain periods in the lower portion of the river. Further, localized problems of screen clogging, etc., could occur. Little data are presently available on the occurence, numbers, and types of plankton present in the river. It is known, however, that the nutrient concentrations, temperatures, and other necessary factors are adequate to sustain abundant plankton populations, and the limited data available show relatively high plankton population during certain summer periods.

2. Public Water Supply Use

The coliform bacteria content of the Yakima River is such that a minimum treatment consisting of chlorination only would be required in all areas and, throughout the majority of the river, complete treatment would be required. In the reaches of the river immediately below Yakima, the bacteria concentration found in the river would preclude its use as a municipal water supply, even with complete treatment, if the Public Health Service recommendations are followed.

The existing and potential problems associated with plankton were mentioned earlier.

3. Recreation and Aesthetic Use

The bacterial concentrations in the headwater areas are very low and should permit all types of recreational activity, including swimming. Throughout the main stem and especially in that portion below the Yakima, the bacterial concentration exceeds the recommended maximum of 240 per 100 ml for swimming during summer periods. Recognizing that certain portions of the lower river may have a low coliform content because of the die-off of populations found upstream, it would seem desirable to examine individual recreation areas separately to determine the adequacy of the water for various recreational uses.

C. Adequacy of Water Data

The adequacy of water data can only be evaluated in light of the use intended for the data. Here, the evaluation is made of the adequacy of the data to gain a general understanding of the Basin's water resources, its present and potential values and limitations.

The Subcommittee on Hydrology of the Columbia Basin Inter-Agency Committee has published a study in which existing and recommended hydrologic data collection stations are listed. Their recommendations call for an increase from 32 to 46 in stream gaging stations, an increase from 8 to 16 in snow survey courses, and no increase in the present number (20) of hydroclimatic stations. The recommended number of water quality sampling stations has been exceeded by recent installations.

Considerably more detailed data are needed to define the nutrients--algal population relationship--and to determine the present and potential effect of their relationship on water use.

The existing system of collecting routine chemical and physical data seems to be adequate with the possible exception of sample scheduling. The present practice is to collect and composite samples at the Parker and Kiona stations until a significant change in conductivity is noted. A new composite is then begun. The two stations are not now correlated in such a manner that the periods of collection coincide; hence, it is difficult to make direct comparisons between the two stations.

An important data collection requirement not now being fully met is for more information on the occurrence, concentrations, and effect of organic pesticides in the Basin. The PHS station at Richland collects this type of information, but peak concentrations which may occur in the Basin cannot be detected because of the diluting effect of the uncontaminated water.

Bacteriological investigations are needed to better define the problems of rural water supply contamination and to explore in general the effect of existing bacterial concentrations on the use of water in the Basin.

APPENDIX

Table 2

Distribution of Employment in the Yakima Basin, 1950 a/
Compared with the Distribution of Employment in Washington and Oregon

Industry Group	Percentage Distribution In Yakima Basin	Percentage Distribution In Washington and Oregon
Goods	41.8	33.4
Agriculture	24.4	10.5
Forestry and fisheries	0.1	0.7
Mining	1.0	0.4
Manufacturing, total	16.3	21.8
Lumber, wood prod., furn. & fix.	1.6	10.0
Food and kindred	3.0	2.5
Chemicals and related	9.5	0.7
Printing and publishing	0.8	1.3
All other manufacturing	1.4	7.3
Services	56.8	65.1
Construction	11.9	7.9
Transp., Comm., Utilities	7.1	8.9
Trade (wholesale and retail)	17.1	20.6
All other services	20.7	27.7
Industry not reported	1.4	1.5
Employed labor force, total	100.0	100.0

a/ Kittitas and Yakima Counties and the portion of Benton County within the Yakima Basin.

TABLE 3

Location	Well Depth (ft)	Temp °F	Color	pH	N.C. Hard	Total Hard	Dis. Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	PO_4
Near Sunnyside	99	61	5	7.9	24	179	315	57	.01	48	14.0	17.0	7.4	0	190	44.0	11.0	0.4	2.3	.07
Near	160	--	--	--	--	87	136	32	.05	22	7.9	6.8	1.9	0	113	5.1	2.7	0.0	2.0	--
Toppenish	863	69	0	7.8	0	42	158	68	.08	13	2.2	19.0	4.1	0	105	0.3	1.0	0.6	0.2	--
Upper	146	---	5	7.7	0	80	155	54	.02	16	9.7	10.0	1.8	0	116	4.4	3.0	0.2	1.6	--
Ahtanum	11	--	10	7.3	0	49	111	47	.11	10	5.8	5.5	3.7	0	74	24.0	0.7	0.2	1.0	--
Valley	384	60	0	7.9	0	54	149	53	.05	13	5.3	17.0	3.2	0	113	0.4	1.8	0.5	0.1	--
	1078	63	8	7.9	0	57	114	38	.24	12	6.6	7.2	3.1	0	85	4.4	1.2	0.3	0.2	--
Lower	18	--	25	7.2	0	117	205	51	.02	24	14.0	16.0	5.6	0	180	5.1	2.5	0.3	1.8	--
Ahtanum	30	--	25	7.2	0	107	209	52	.03	23	12.0	19.0	5.3	0	160	8.0	11.0	0.2	1.5	--
Valley	213	--	5	7.3	32	141	251	61	.03	30	16.0	9.6	3.2	0	133	29.0	18.0	0.3	2.7	--
In Yakima	85	--	15	7.3	35	130	221	39	.02	34	11.0	12.0	4.8	0	116	21.0	26.0	0.3	6.0	--
Wenas	Spring	59	--	7.6	0	158	262	66	.02	32	19.0	13.0	5.8	0	193	18.0	9.1	0.2	3.1	--
Valley	127	--	--	8.3	11	183	309	58	.02	42	19.0	23.0	2.9	0	210	21.0	20.0	0.4	1.6	--
	60	--	--	7.7	0	256	445	53	.03	60	26.0	62.0	4.8	0	442	20.0	5.2	0.4	6.2	--
	385	55	--	7.2	0	90	167	42	.13	12	7.2	23.0	5.0	0	124	9.8	2.0	0.4	0.1	--
	400	--	--	7.5	0	107	205	59	.03	23	12.0	13.0	4.0	0	146	10.0	5.2	0.2	2.1	--
	115	--	--	7.4	0	78	162	61	.07	16	9.2	8.8	4.8	0	116	3.3	2.4	0.2	0.7	--
	Spring	62	--	7.7	0	57	156	53	.06	12	6.6	17.0	4.3	0	104	9.2	1.8	0.4	0.3	--
Selah	121	54	5	7.9	0	338	559	57	.00	84	31.0	58.0	6.3	0	459	60.0	13.0	0.6	7.0	--

Continued

TABLE 3 (Continued)

Location	Well Depth (ft)	Temp °F	Color	pH	N.C. Hard	Total Hard	Dis. Solids	SiO_2	Fe	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	PO_4
Yakima	550	62	5	7.6	0	152	272	49	.03	33	17.0	30.0	4.9	0	225	19.0	8.4	0.6	4.6	--
Firing Center*	550	68	0	7.8	0	83	174	49	.04	16	11.0	18.0	3.7	0	147	0.6	3.9	0.5	0.2	--
						Benton County														
Prosser	502	66	0	7.7	0	56	229	59	.05	14	5.1	43.0	12	0	187	4.8	6.5	0.6	0.2	.11
	599	63	0	7.5	0	68	248	50	.12	17	6.1	54.0	9.8	0	221	0.1	11.0	0.9	0.2	.08
	740	60	5	7.8	0	67	236	46	.06	16	6.6	46.0	10	0	202	0.6	9.5	0.7	0.1	.09
North of Benton City	420	--	5	7.7	38	182	262	51	.68	38	.21	13.0	4.8	0	[illegible]	4.3	7.5	0.2	4.5	--
North of Richland	228	--	5	9.2	0	39	130	18	.05	9.2	3.8	25.0	4.8	16	58	2.1	10.0	1.0	0.3	--
						Kittitas County														
Ellensburg	1209	55	0	7.4	0	83	151	58	.02	18	9.2	8.6	2.0	0	120	1.3	2.0	0.2	0.8	.25

*Averages of several wells.

Yakima River Flow Data
(cfs)

1955 Date	Flow at Parker	1½ Day Lag at Parker	Flow at Kiona	Difference (Return)
July				
30	808			
31	812			
August				
1	876	810	2230	1420
2	888	844	2260	1416
3	648	882	2270	1388
4	536	768	2260	1492
5	380	592	2100	1508
6	620	458	1900	1542
7	609	500	1800	1330
8	662	615	1910	1295
9	574	636	1840	1204
10	420	618	1720	1102
11	623	497	1660	1163
12	350	522	1530	1008
13	592	487	1560	1073
14	748	471	1490	1019
15	836	620	1750	1130
16	800	792	1810	1092
17	654	818	1840	1022
18	707	727	1720	993
19	724	681	1710	1029
20	612	715	1780	1065
21	469	668	1730	1062
22	568	541	1750	1209
23	462	519	1850	1331
24	480	515	1790	1275
25	355	471	1790	1319
26	364	418	1740	1322
27	463	359	1690	1331
28	336	414	1780	1366
29	402	400	1780	1380
30	443	369	1790	1420
31	324	423	1840	1417

Yakima River Flow Data
(Continued) (cfs)

1955 Date	Flow at Parker	1½ Day Lag at Parker	Flow at Kiona	Difference (Return)
	443			
	329			
Sept.				
1	494	384	1830	1446
2	608	409	1780	1371
3	441	551	2050	1499
4	426	525	2050	1525
5	426	434	1940	1506
6	402	426	1950	1524
7	453	414	1960	1546
8	461	428	1950	1522
9	318	457	2000	1543
10	232	390	1980	1590
11	287	275	1910	1635
12	250	240	1890	1650
13	374	249	1880	1631
14	414	312	1920	1608
15	452	413	2010	1597
16	694	433	2100	1667
17	808	578	2500	1922
18	496	751	2570	1719
19	508	652	2450	1898
20	283	502	2320	1818
21	204	396	2180	1784
22	156	244	2020	1776
23	312	180	1960	1780
24	261	234	1980	1746
25	189	287	1980	1693
26	240	225	1940	1715
27	260	215	2000	1785
28	565	250	2000	1750
29	421	413	2060	1547
30	352	493	2240	1747

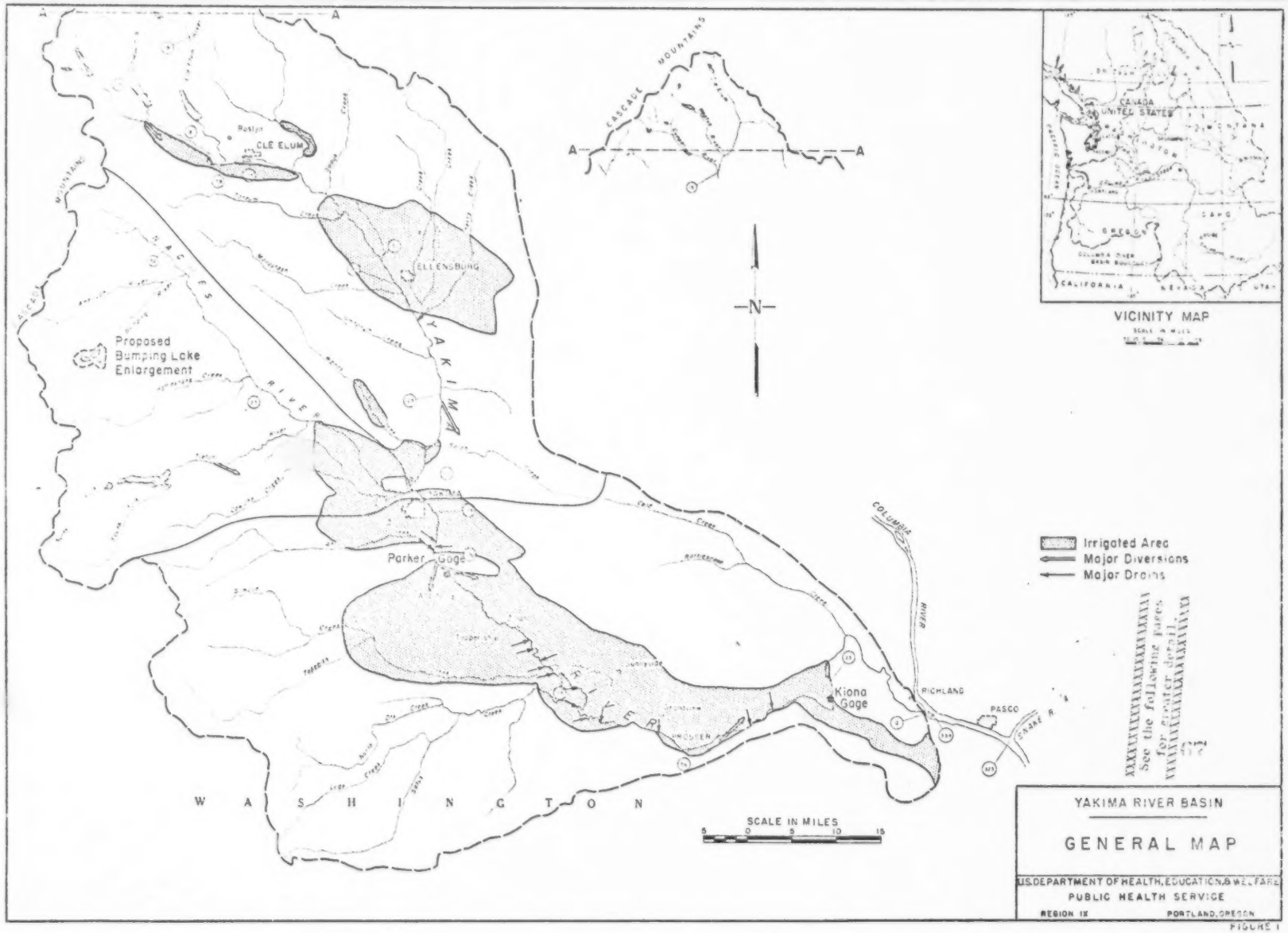
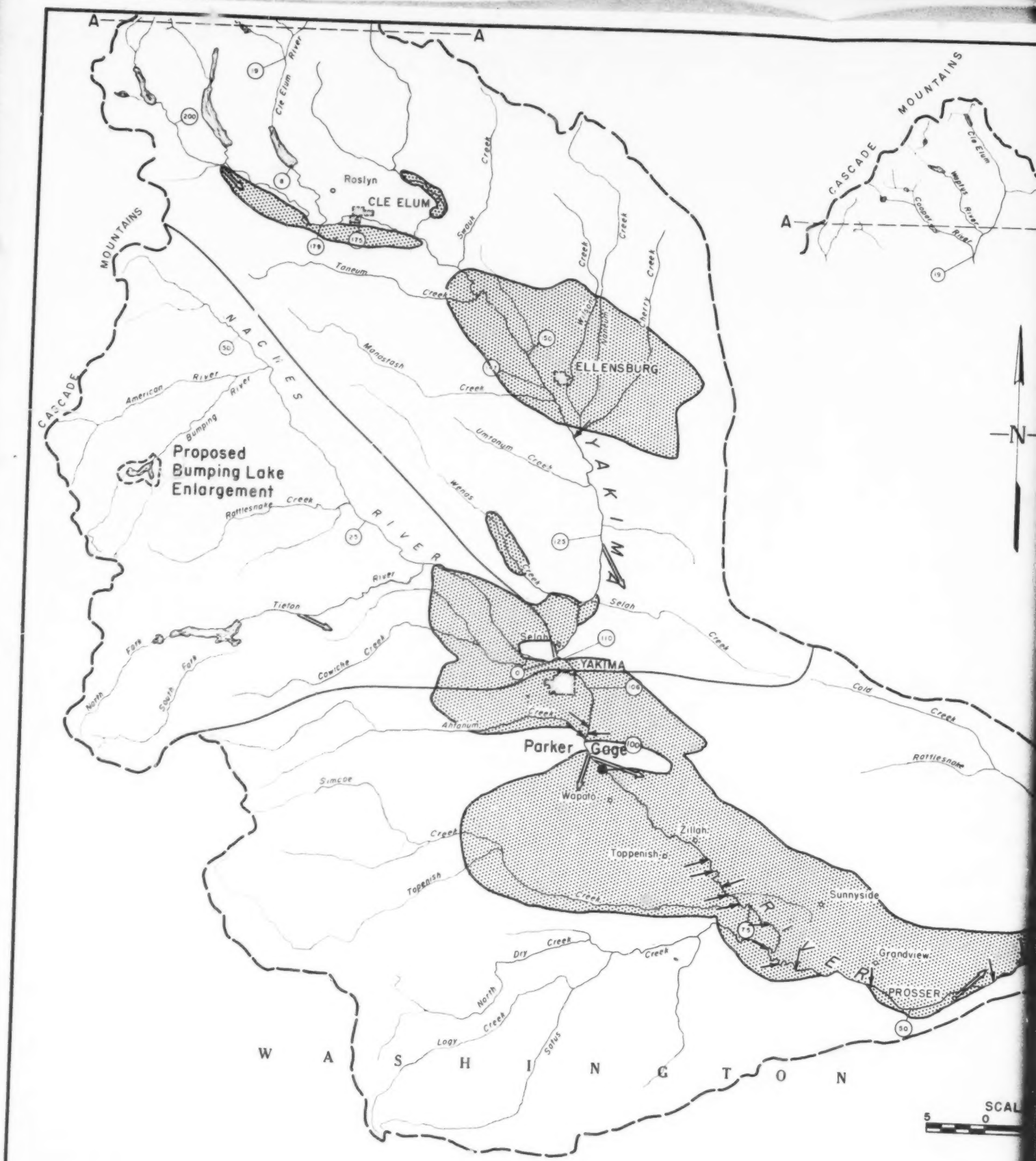

CLE ELUM
ELLENSBURG
Proposed
Bumping Lake
Enlargement
YAKIMA
RIVER
Parker Gage
Kiona
Gage
RICHLAND
PASCO
COLUMBIA
RIVER
YAKIMA
RIVER
W A S H I N G T O N
CASCADE MOUNTAINS
A
A
N
SCALE IN MILES
5 0 5 10 15
Irrigated Area
Major Diversions
Major Drains
See the following Pages
for greater detail.
VICINITY MAP
CANADA
UNITED STATES
CALIFORNIA
NEVADA
UTAH
YAKIMA RIVER BASIN
GENERAL MAP
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION IX
PORTLAND, OREGON

FIGURE 1


A
A
CASCADE MOUNTAINS
Cle Elum River
Roslyn
CLE ELUM
Teanum Creek
Manastash Creek
ELLENSBURG
Umtanum Creek
Wenas Creek
YAKIMA RIVER
Selah Creek
YAKIMA
Ahtanum Creek
Parker Gage
Wapato
Toppenish
Toppenish Creek
Simcoe Creek
Zillah
Sunnyside
Grandview
PROSPER
Dry Creek
North Logy Creek
Satus Creek
Rattlesnake Creek
Cowiche Creek
Tieton River
American River
Bumping River
Proposed Bumping Lake Enlargement
WASHINGTON
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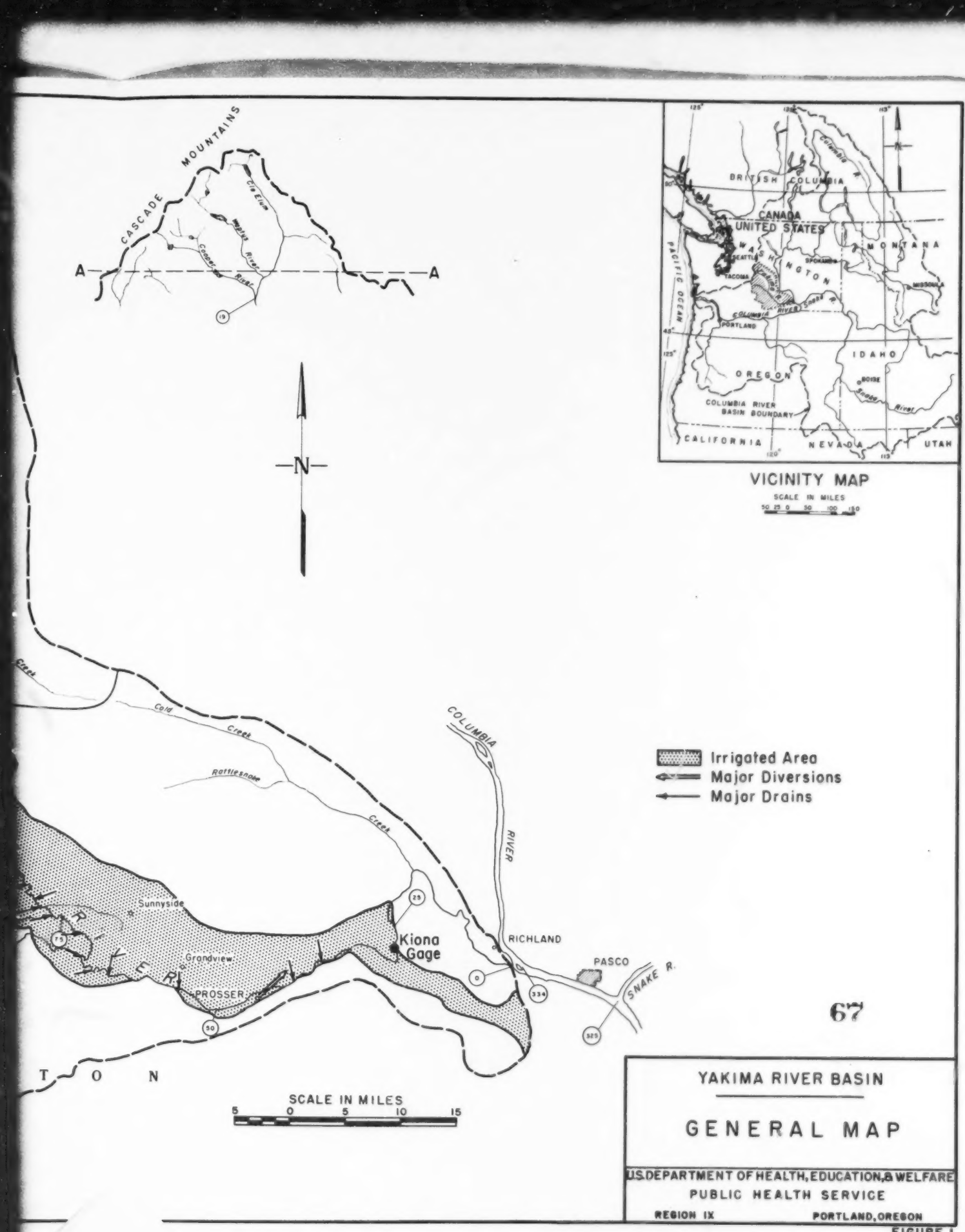

67

YAKIMA RIVER BASIN

GENERAL MAP

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION IX PORTLAND, OREGON

FIGURE 1

STATION NO. 1

Donald-Wapato Bridge
Water and Air Temperatures in Degrees of Fahrenheit

	August						September					
1955	Water Temp.			Air Temp.			Water Temp.			Air Temp.		
Date	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
1	65	57	61	84	61	73	56	48	52	88*	53	71
2	62	56	59	79	60	70	57	50	53	89	55	72
3	61	53	57	80	56	68	58	51	54	92	62	77
4	62	53	57	86	54	69	58	51	54	91	58	75
5	64	55	59	90	55	72	57	50	53	91	56	73
6	64	56	60	95	57	76	57	50	53	91	58	74
7	64	56	60	92	62	77	55	51	53	87	71	79
8	62	55	58	85*	55	70	54	49	51	76	63	70
9	62	53	57	85	55	70	55	48	52	82	53	67
10	63	53	58	90	55	72	56	48	52	84	53	68
11	62	55	58	87*	69	78	55	47	51	82	59	71
12	62	53	58	81	62	71	53	46	49	78*	47*	63
13	58	51	54	81	55	68	48	47	48	65	50*	57
14	59	51	55	84*	55	70	47	45	46	65	50	57
15	59	51	55	87*	61	74	47	43	45	64	46	50
16	59	52	55	85*	62	74	48	43	46	67	46	56
17	60	52	55	86	59	68	48	42	45	70	46	58
18	60	52	56	87*	59	74	49	43	45	76	51	64
19	61	53	56	88	68	78	50	44	47	80	46	63
20	60	53	56	82	60	71	50	45	47	67	47	57
21	58	50	54	81*	51	68	46	42	44	64	47	56
22	59	51	55	83*	60	72	45	40	43	65	37	51
23	58	50	54	81	59	70	48	41	44	72	46	59
24	57	49	52	80	57	69	48	43	45	71	43	57
25	56	48	52	77	53	65	47	41	44	73	40	56
26	56	48	53	78	55	67	46	41	43	70	38	54
27	57	48	52	83	53	68	44	43	44	58	55	56
28	57	49	53	81	60	71	45	41	43	64	45	60
29	57	49	53	88	53	70	45	39	42	68	39	53
30	57	50	53	89	59	74	45	39	42	69	41	55
31	57	49	53	86	54	70						

*Estimate

STATION NO. 2

Chandler
Water and Air Temperatures in Degrees of Fahrenheit

1955	August						September					
	Water Temp.			Air Temp.			Water Temp.			Air Temp.		
Date	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
1	74	67	70	88	60	74	73	63	68	96	46	71
2	74	66	70	86	48	67	72	64	68	97	48	73
3	73	65	69	84	45	63	72	65	69	94	54	74
4	73	64	69	87	46	67	72	65	68	92	68	80
5	75	64	69	96	50	73	72	65	69	94	52	73
6	76	66	71	99	52	76	71	56	68	96	57	76
7	75	67	71	97	57	77	71	65	68	92	59	76
8	75	67	71	87	53	70	67	64	66	80	58	69
9	75	66	71	88	48	68	69	62	66	89	53	71
10	76	66	71	95	50	73	69	62	66	89	51	70
11	77	67	72	95	54	75	69	62	65	87	54	71
12	74	66	70		48	66	68	61	65		44	69
13	73	64	68	85	46	66	64	61	63	75	46	60
14	74	64	69	90	46	68	61	60	60	68	54	61
15	74	65	69	90	49	70	60	56	58	68	43	55
16	74	65	69	89	51	70	62	57	59	72	50	61
17	74	65	70	92	50	71	62	56	59	72	38	54
18	76	66	71	98	53	75	62	57	59	74	41	57
19	75	67	71	94	56	75	63	57	60	83	43	57
20	74	66	70	89	53	71	63	59	61	74	52	63
21	74	64	69	86	51	69	60	57	59	66	43	54
22	74	65	69	92	53	72	60	55	58	66	33	49
23	73	65	69	98	53	75	61	56	58	70	43	57
24	72	64	68	85	52	68	60	55	57	70	36	53
25	70	63	66	80	47	63	61	54	57	73	34	53
26	71	62	66	84	43	63	60	54	57	79	44	61
27	71	62	66	85	43	64	58	57	57	62	56	59
28	71	63	67	84	43	64	70	55	57	68	43	55
29	71	62	67		47	68	59	54	57		35	51
30	73	63	68	89	46	67	60	54	57	70	36	53
31	72	74	68	94	45	69						

62

STATION NO. 3

Richland
Water and Air Temperatures in Degrees of Fahrenheit

	August						September					
1955	Water Temp.			Air Temp.			Water Temp.			Air Temp.		
Date	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
1	75	69	72	95	67	81	74	66	70	98	53	76
2	74	68	71	91	54	73	74	68	71	99	55	77
3	74	66	70	87	52	70	75	69	72	101	61	81
4	75	67	71	88	54	71	73	68	71	101	65	83
5	76	68	72	94	56	75	74	68	71	99	60	80
6	78	69	74	100	61	81	72	69	71	101	62	82
7	77	70	74	104	64	84	72	68	70	101	64	83
8	77	69	73	100	59	80	70	65	68	96	60	78
9	76	69	73	91	57	74	71	66	69	84	55	70
10	77	69	73	94	60	77	70	66	68	91	54	73
11	77	70	74	100	62	81	69	64	67	95	56	76
12	77	70	74	101	55	78	66	65	66	90	48	69
13	75	68	72	90	57	74	65	61	63	83	50	67
14	74	68	71	90	54	72	60	58	59		56	67
15	74	69	72		57	76	63	59	61	78	50	64
16	74	68	71	95	58	77	63	59	61	69	51	60
17	75	67	71	92	56	74	64	59	62	73	44	59
18	76	69	73	96	60	78	64	60	62	74	48	61
19	76	70	73	99	67	83	64	60	62	79	46	63
20	76	70	73	95	59	77	63	61	63	85	56	71
21	75	68	72	88	55	72	61	57	59	75	48	62
22	74	68	71	92	56	74	62	58	60	71	37	54
23	73	67	70	94	55	75	61	58	60	73	48	61
24	73	67	70	91	54	73	62	57	60	76	40	58
25	72	65	69	87	55	71	61	57	59	75	40	58
26	71	65	68	81	49	65	60	59	60	76	45	61
27	72	66	69	89	51	70	60	58	59	81	57	69
28	71	66	69	92	61	77	60	57	59	68	48	58
29	72	66	69	89	54	73	61	57	59	68	42	55
30	73	66	70	98	57	78				69	40	55
31	73	67	70	102	57	80						